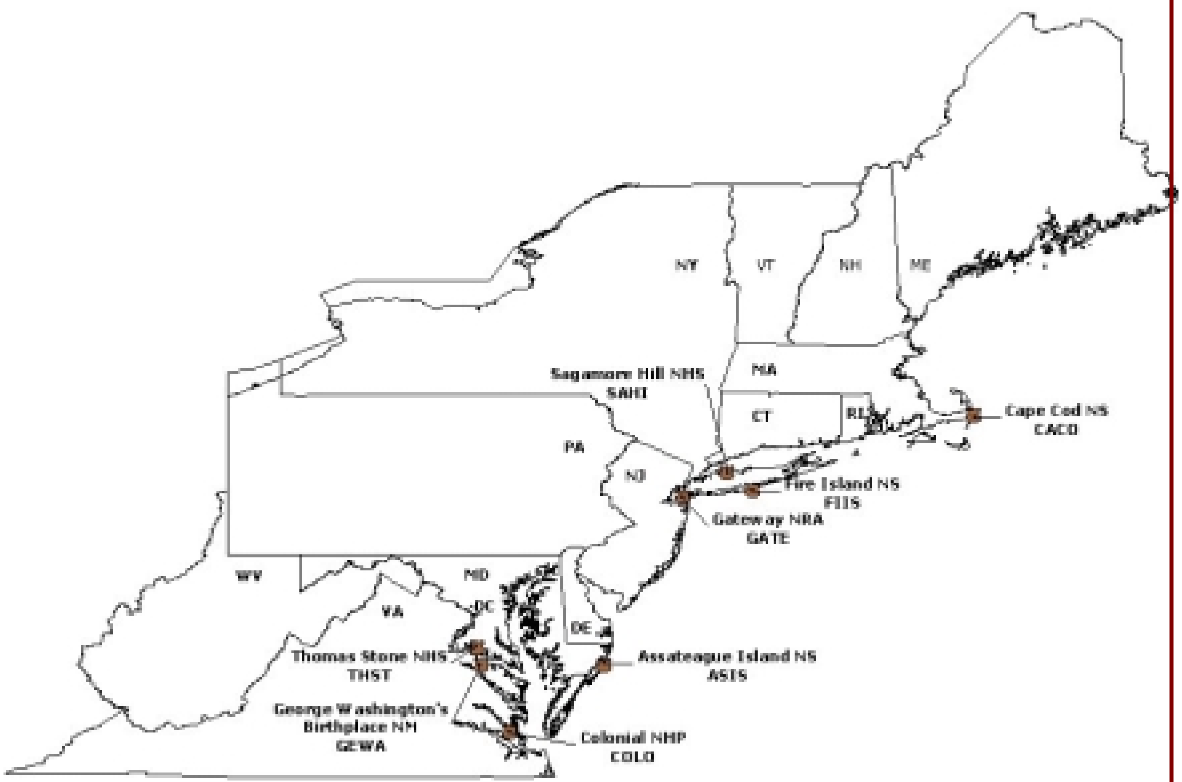
National Park Service Inventory and Monitoring Program

Northeast Coastal and Barrier Network Vital Signs Monitoring Plan (NCBN)

Phase II

October 2003



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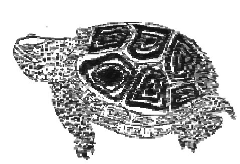

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CHAPTER 1 INTRODUCTION AND BACKGROUND

PURPOSE

Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in national parks is fundamental to the Service's ability to manage park resources "unimpaired for the enjoyment of future generations". National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the benefit of park resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach because most parks are open systems, with threats such as air and water pollution, or invasive species, originating outside of the park's boundaries. An ecosystem approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level, and in some cases may require a regional, national or international effort to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

Natural resource monitoring provides site-specific information needed to understand and identify change in complex, variable, and imperfectly understood natural systems and to determine whether observed changes are within natural levels of variability or may be indicators of unwanted human influences. Thus, monitoring provides a basis for understanding and identifying *meaningful change* in natural systems characterized by complexity, variability, and surprises. Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need to initiate or change management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999; Appendix 1).

The intent of the NPS monitoring program is to track a subset of park resources and processes, known as "vital signs", that are determined to be the most significant indicators of ecological condition of those specific resources that are of the greatest concern to each park. This subset of resources and processes is part of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on these resources. In situations where natural areas have been so highly altered that physical and biological processes no longer operate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

<u>Legislation, Policy and Guidance</u>

National Park managers are directed by federal law and National Park Service policies and guidance to know the status and trends in the condition of natural resources under their stewardship in order to fulfill the NPS mission of conserving parks unimpaired (Appendix 2). The mission of the National Park Service (National Park Service Organic Act, 1916) is:

> "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*".

Congress strengthened the National Park Service's protective function, and provided language important to recent decisions about resource impairment, when it amended the Organic Act in 1978 to state that *"the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…"*.

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to "*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System*", and to *"… assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

> *"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

The 2001 NPS Management Policies updated previous policy and specifically directed the Service to inventory and monitor natural systems:

> *"Natural systems in the national park system, and the human influences upon them, will be*

monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions".

Further, *"The Service will:*

- *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.*
- *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.*
- *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.*
- *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.*
- *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems".*

Additional statutes provide legal direction for expending funds to determine the condition of natural resources in parks and specifically guide the natural resource management of network parks, including:

- Taylor Grazing Act 1934;
- Fish and Wildlife Coordination Acts, 1958 and 1980;
- Wilderness Act 1964;
- National Historic Preservation Act 1966;
- National Environmental Policy Act of 1969
- Clean Water Act 1972, amended 1977, 1987;
- Endangered Species Act 1973, amended 1982
- Migratory Bird Treaty Act, 1974;
- Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976
- Mining in the Parks Act 1976;
- American Indian Religious Freedom Act 1978;
- Archaeological Resources Protection Act 1979;
- Federal Cave Resources Protection Act 1988;
- Clean Air Act, amended 1990;

MONITORING GOALS AND STRATEGIES

Role of Inventory, Monitoring, and Research in Resource Management

Monitoring is a central component of natural resource stewardship in the National Park Service, and in conjunction with natural resource inventories and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Figure 1; see also Appendix 3). The NPS strategy to institutionalize inventory and monitoring throughout the agency consists of a framework (Appendix 4) having three major components: (1) completion of 12 basic resource inventories upon which monitoring efforts can be based; (2) a network of 11 experimental or "prototype" long-term ecological monitoring (LTEM) programs begun in 1992 to evaluate alternative monitoring designs and strategies; and (3) implementation of operational monitoring of critical parameters (i.e. "vital signs") in approximately 270 parks with significant natural resources that have been grouped into 32 vital sign networks linked by geography and shared natural resource characteristics.

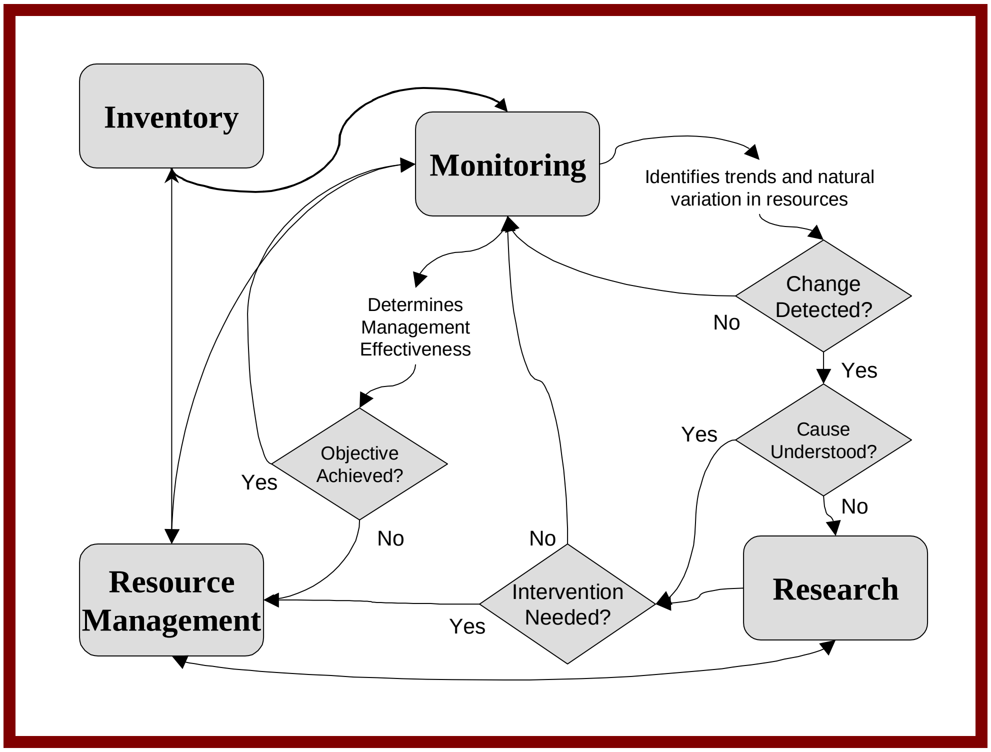

Figure 1. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modifed from Jenkins *et al*. 2002).

To implement natural resource monitoring in approximately 270 parks with significant natural resources, the NPS has organized parks into 32 'vital signs monitoring networks' linked by geography and shared natural resource characteristics. The network approach will facilitate collaboration, information sharing, and economies of scale in natural resource monitoring, and will provide parks with a minimum infrastructure for initiating natural resource monitoring that can be built upon in the future. Eleven of the 32 networks include one or two prototype long-term ecological monitoring (LTEM) programs, which were established as experiments to learn how to design scientifically credible and cost-effective monitoring programs in ecological settings of major importance to a number of NPS units. Because of higher funding and staffing levels, as well as USGS involvement and funding in program design and protocol development, the prototypes serve as "centers of excellence" that are able to do more extensive and in-depth monitoring and continue research and development work to benefit other parks. In the Northeast Coastal and Barrier Network, Cape Cod National Seashore is the prototype for the Atlantic coastal biome (Appendix 3).

Vital Signs Monitoring Goals

Servicewide Goals for Vital Signs Monitoring for the National Park Service are as follows:

- Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.

- Provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.

Strategic Approaches to Monitoring

Scope and Process for Developing an Integrated Monitoring Program

During the development of the vision for park vital signs monitoring, it was clear that a single approach to monitoring design would not be effective in the NPS considering the tremendous variability among parks in ecological conditions, sizes, and management capabilities. To develop an effective and cost-efficient monitoring program that addresses the most critical information needs of each park and integrates with other park operations such as interpretation and maintenance activities, parks need considerable flexibility to allow existing programs, funding and staffing to be combined with new funding and staffing available through the Natural Resource Challenge and the various divisions of the Natural Resource Program Center. Partnerships with federal and state agencies and adjacent landowners are necessary to effectively understand and manage resources and threats that extend beyond park boundaries, but these partnerships (and the appropriate ecological indicators and methodologies involved) differ for parks throughout the national park system.

The complicated task of developing a network monitoring program requires an initial investment in planning and design to guarantee that monitoring meets the most critical information needs of each park and produces scientifically credible results that are clearly understood and accepted by scientists, policy makers, and the public, and that are readily accessible to managers and researchers. These front-end investments also ensure that monitoring will build upon existing information and understanding of park ecosystems and make maximum use of leveraging and partnerships with other agencies and academia.

Each network of parks is required to design an integrated monitoring program that addresses the monitoring goals listed above and is tailored to the high-priority monitoring needs and partnership opportunities for the parks in that network. Although there will be considerable variability among networks in the final design, the basic approach to designing a monitoring program should follow five basic steps, which are further discussed in the Recommended Approach for Developing a Network Monitoring Program (Appendix 5):

1. Define the purpose and scope of the monitoring program.
2. Compile and summarize existing data and understanding of park ecosystems.
3. Develop conceptual models of relevant ecosystem components.
4. Select indicators and specific monitoring objectives for each; and
5. Determine the appropriate sampling design and sampling protocols.

These steps are incorporated into a 3-phase planning and design process that has been established for the monitoring program. Phase I of the process involves defining goals and objectives; beginning the process of identifying, evaluating and synthesizing existing data; developing draft conceptual models; and completing other background work that must be done before the initial selection of ecological indicators. Each network is required to document these tasks in a Phase I report, which is then peer reviewed and approved at the regional level before the network proceeds to the next phase. (The Phase I report is a first draft of the chapters of the final monitoring plan that present the Introduction/Background and Conceptual Models). The Northeast Coastal and Barrier Network (NCBN) completed the Network's Phase I report on October 1, 2002 (Appendix 6). Phase II of the planning and design effort involves prioritizing and selecting vital signs and developing specific monitoring objectives for each that will be included in the network's initial integrated monitoring program. The Phase II report for the NCBN was completed October 1, 2003. Phase III entails the detailed design work needed to implement monitoring, including the development of sampling protocols, a statistical sampling design, a plan for data management and analysis, and details on the type and content of various products of the monitoring effort such as reports and websites. The NCBN will have completed a draft Phase III report in December, 2004.

The standard process used by many of the vital signs network, including the NCBN, to select a subset of park resources and processes for monitoring is depicted in Figure 2 below. In the fall of 1999, through the year 2000 the first three steps of the seven-step plan; forming a steering committee and board of directors, summarizing existing data and understanding, and preparing for and holding a Network Vital Signs Scoping Workshop, recommended by the National Monitoring Program were addressed by the Network. The NCBN Steering Committee was organized and established to advise and assist in decision making on issues regarding the development and implementation of a coastal park monitoring strategy, hiring of permanent and temporary staff, budgeting, scheduling, and promoting accountability for the program. Members of the steering committee were nominated by park staff, the regional I&M coordinator and regional chief scientists. Those selected include scientists familiar with Northeast coastal park issues or those who have been involved with or implemented research pertaining to coastal ecosystem monitoring.

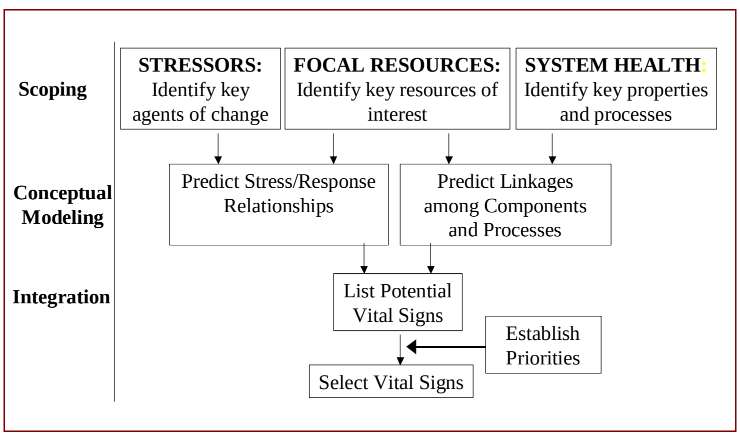

Figure 2. Basic approach to identifying and selecting vital signs for integrated monitoring of park resources (source: Kurt Jenkins, USGS Olympic Field Station).

A NCBN Board of Directors was also formed to help manage and oversee the program. The Board includes the seven superintendents (THST and GEWA share a superintendent) from the coastal parks, two chief scientists from the region, the regional inventory and monitoring coordinator and the network inventory and monitoring coordinator. The board works closely with the Network Data

Manager and the Technical Steering Committee to insure monitoring goals are met. There is at least one board meeting a year. Their major responsibilities are to assure accountability and effectiveness for the Network Monitoring Program by reviewing progress, quality control, and spending of Network funds. The Board also assists in developing strategies and procedures for leveraging network funds and personnel to best accomplish inventory and monitoring and other natural resource needs of Network parks. They are consulted on the hiring of Network personnel using funding provided to the Network, including base funds and other sources. They also play an important role in seeking additional financial support to leverage the Servicewide funds and solicit professional guidance from and partnerships with other governmental agencies, organizations and individuals.

Tasked with the development of a network-wide monitoring program the Technical Steering Committee agreed that the general aim and goals of the Cape Cod National Seashore (CACO) prototype long-term monitoring program could help provide initial structure and basis for the development of the NCBN monitoring program. In 1996, CACO was identified as a prototype park for long-term ecological monitoring within the Atlantic and Gulf Coast biogeographic region. Development of the CACO long-term ecological monitoring program has been a collaborative effort primarily between U.S. Geological Survey (USGS) and NPS. Although USGS provided the bulk of the funding for development of a conceptual framework for the CACO program and for protocol development, the park began receiving funding specifically for the long-term monitoring program in 1997. In 1999 the "Conceptual Framework for the Development of Long-term Monitoring Protocols at Cape Code National Seashore" was completed (Roman and Barrett 1999; Appendix 1). As a prototype park and in partnership with USGS, CACO was charged with developing and refining long-term monitoring protocols that could be of utility to other Atlantic and Gulf Coast parks, in addition to supporting management of Cape Cod's natural resources. With the advent of the network approach to inventory and monitoring, the park's mission has expanded to include focused technical support to the Northeast and Coastal and Barrier Network.

Implementation of a Water Quality Monitoring Component for the NCBN

The implementation plan for the water quality monitoring component that is funded by the NPS Water Resources Division is keyed to the concept of fully integrating the design and implementation of water quality monitoring with the network-based vital signs monitoring program. Networks incorporate the 3-phase approach and follow the same implementation schedule for their water quality monitoring planning. Networks have the option of producing a single, integrated monitoring plan that incorporates the "core vital signs" and water quality monitoring components, or they can produce a separate document for the water quality monitoring component that follows the detailed guidance for water quality monitoring developed by the Water Resources Division (see http://science.nature.nps.gov/im/monitor/vsmTG.htm - TechGuide).

The NCBN will produce a single, integrated monitoring plan that incorporates the "core vital signs" and water quality components. The Network has been working towards identifying key water quality vital signs. As a result of the first network Vital Signs Scoping Workshop, held in April 2000, freshwater quality and estuarine water quality workgroups were put together, met to discuss water quality monitoring and issues for the network and produced reports (Appendices 7 and 8). In 2001, a cooperative agreement was established with two scientists to develop a freshwater water quality report. A draft is currently available (Appendix 9). Estuarine water quality has also been identified by all network parks as a key consideration in the development of the network monitoring program. A report was developed by USGS scientists evaluating estuarine water quality (estuarine nutrients) in all the network parks (Appendix 10).

Strategies for Determining What to Monitor

Monitoring is an on-going effort to better understanding how to sustain or restore ecosystems, and serves as an "early warning system" to detect declines in ecosystem integrity and species viability before irreversible loss has occurred. As our understanding of ecological systems and the concepts of sustainability and integrity of natural systems has evolved, the classic view of the "balance of nature" has been replaced by a non-equilibrium paradigm which recognizes that ecological systems are regularly subject to natural disturbances such as droughts, floods, and fire, that alter the composition and structure of the systems and the processes that shape them. Even in the absence of human activities, ecosystems are characterized by high variability in composition, structure and function. The goals of the vital signs monitoring program recognize the dynamic nature and condition of park ecosystems and the need to identify and separate 'natural' variation from undesirable anthropogenic sources of change to park resources.

One of the key initial decisions in designing a monitoring program is deciding how much relative weight should be given to tracking changes in focal resources and stressors that address current management issues, versus measures that are thought to be important to long-term understanding of park ecosystems and may provide early-warning of presently unforeseen issues and threats to the sustainability or resilience of park ecosystems. Ultimately, an indicator or "vital sign" is useful only if it can provide information to support a management decision or to quantify the success of past decisions, and a useful ecological indicator must produce results that are clearly understood and accepted by managers, scientists, policy makers, and the public. However, our current understanding of ecological systems and consequently, our ability to predict how park resources might respond to changes in various system drivers (agents of change) and stressors is poor. A monitoring program that focuses only on current threat/response relationships and current issues may not provide the long-term data and understanding needed to address high-priority issues that will arise in the future.

Should vital signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status? Woodley *et al*. 1993, Woodward *et al*. (1999), Jenkins *et al*. (2002) and others have described some of the advantages and disadvantages of various monitoring approaches, including a strictly threats-based monitoring program, or alternate taxonomic, integrative, reductionist, or hypothesis-testing monitoring designs (Woodley *et al*. 1993, Woodward *et al*. 1999). The approach adopted by most I&M networks agrees with the assertion that the best way to meet the challenges of monitoring in national parks and other protected areas is to achieve a balance among different monitoring approaches, while recognizing that the program will not succeed without also considering political issues. The I&M Program has adopted a multi-faceted approach for monitoring park resources, based on both integrated and threat-specific monitoring approaches and building upon concepts presented originally for the Canadian national parks (See Figure 3; Woodley *et al*. 1993).

Choosing indicators or "vital signs" in each of the following broad categories is recommended:

(1) **Ecosystem Agents of Change** that fundamentally affect park ecosystems,
(2) **Stressors** and their ecological effects on the ecosystem **(Ecosystem Responses),**
(3) **Focal Resources** of parks, and
(4) **Key Properties and Processes of Ecosystem Integrity**.

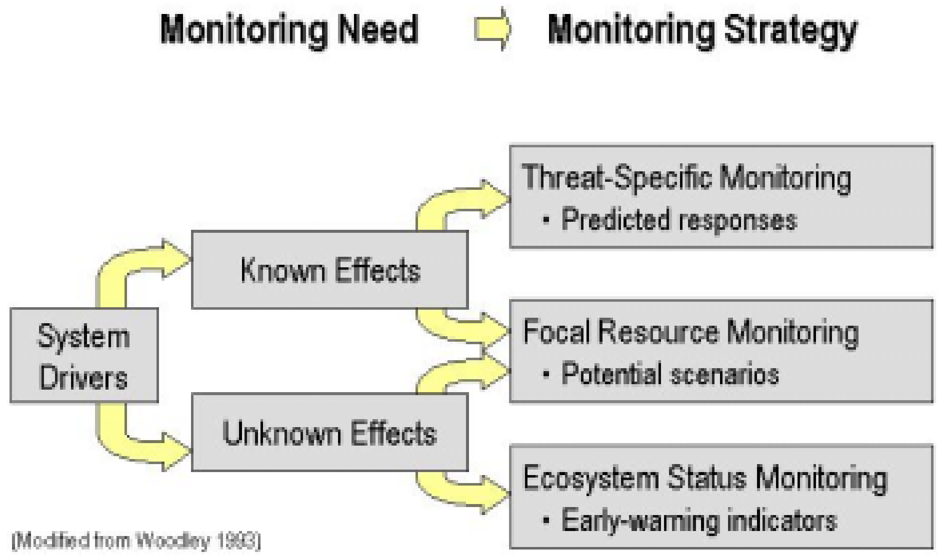

Figure 3. Conceptual approach for selecting monitoring indicators. In certain cases where potential effects and responses by park resources are well understood (Known Effects), monitoring of drivers (agents of change), stressors, and park ecosystem responses is conducted. A set of focal resources (including ecological processes) will be monitored to address both known and unknown effects of agents of change and stressors on park resources. Key properties and processes of ecosystem status and integrity will be monitored to improve long-term understanding and potential early warning of undesirable changes in park resources.

Agents of change, or the major external activities or processes that influence the natural system (natural processes or human activities) such as; sea level rise, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., hurricanes, droughts, floods) that have large scale influences on natural systems. Trends in agents of change will suggest what kind of changes to expect and may provide an early warning of presently unforeseen changes to the ecosystem.

Stressors are the associated problems or products of human activities or natural events that alter the quality or integrity of the ecosystem (problems emerging from or related to the agents of change). Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include altered hydrology, altered landscape, invasive species, altered sediment and chemical inputs. Monitoring of stressors and their effects, where known, will ensure short-term relevance of the monitoring program and provide information useful to management of current issues.

Focal resources, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Monitoring of **key properties and processes of ecosystem integrity** will provide the long-term baseline needed to judge what constitutes unnatural variation in park resources and provide early warning of unacceptable change. Biological integrity has been defined as the capacity to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region (Karr and Dudley 1981).

Ecological integrity is the summation of physical, chemical, and biological integrity, and it implies that ecosystem structures and functions are unimpaired by human-caused stresses. Indicators of ecosystem integrity are aimed at early-warning detection of presently unforeseeable detriments to the sustainability or resilience of ecosystems.

Collectively, these basic strategies for choosing monitoring indicators achieve the diverse monitoring goals of the National Park Service.

Integration: Ecological, Spatial, Temporal and Programmatic

One of the most difficult aspects of designing a comprehensive monitoring program is integration of monitoring projects so that the interpretation of the whole monitoring program yields information more useful than that of individual parts. Integration involves ecological, spatial, temporal and programmatic aspects:

- **Ecological Integration** involves considering the ecological linkages among system drivers and the components, structures, and functions of ecosystems when selecting monitoring indicators. An effective ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem. One approach for effective ecological integration is to select indicators at various hierarchical levels of ecological organization (e.g., landscape, community, population, genetic; see Noss 1990).

- **Spatial Integration** involves establishing linkages of measurements made at different spatial scales within a park or network of parks, or between individual park programs and broader regional programs (i.e., National Park Service or other national and regional programs). It requires understanding of scalar ecological processes, the collocation of measurements of comparably scaled monitoring indicators, and the design of statistical sampling frameworks that permit the extrapolation and interpolation of scalar data.

- **Temporal Integration** involves establishing linkages between measurements made at various temporal scales. It will be necessary to determine a meaningful timeline for sampling different indicators while considering characteristics of temporal variation in these indicators. For example, sampling changes in the structure of a forest overstory (e.g., size class distribution) may require much less frequent sampling than that required to detect changes in the composition or density of herbaceous groundcover. Temporal integration requires nesting the more frequent and, often, more intensive sampling within the context of less frequent sampling.

- **Programmatic Integration** involves the coordination and communication of monitoring activities within and among parks, among divisions of the NPS Natural Resource Program Center, and among the NPS and other agencies, to promote broad participation in monitoring and use of the resulting data. At the park or network level, for example, the involvement of a park's law enforcement, maintenance, and interpretative staff in routine monitoring activities and reporting results in a well-informed park staff, wider support for monitoring, improved potential for informing the public, and greater acceptance of monitoring results in the decision-making process. The systems approach to monitoring planning and design requires a coordinated effort by the NRPC divisions of Air Resources, Biological Resource Management, Geologic Resources, Natural Resource Information, and Water Resources to provide guidance, technical support and funding to the networks. Finally, there is a need for the NPS to coordinate monitoring planning, design and implementation with other agencies to promote sharing of data among neighboring land management agencies, while also providing context for interpreting the data.

Limitations of the Monitoring Program

Managers and scientists need to acknowledge limitations of the monitoring program that are a result of the inherent complexity and variability of park ecosystems, coupled with limited time, funding, and staffing available for monitoring. Ecosystems are loosely-defined assemblages that exhibit characteristic patterns on a range of scales of time, space, and organization complexity (De Leo and Levin 1997). Natural systems as well as human activities change over time, and it is extremely challenging to separate natural variability and desirable changes from undesirable anthropogenic sources of change to park resources. The monitoring program simply cannot address all resource management interests because of limitations of funding, staffing, and logistical constraints. Rather, the intent of vital signs monitoring is to monitor a select set of ecosystem components and processes that reflect the condition of the park ecosystem and are relevant to management issues. Cause and effect relationships usually cannot be demonstrated with monitoring data, but monitoring data might suggest a cause and effect relationship that can then be investigated with a research study. As monitoring proceeds, as data sets are interpreted, as our understanding of ecological processes is enhanced, and as trends are detected, future issues will emerge (Roman and Barrett 1999; Appendix 1). The monitoring plan should therefore be viewed as a working document, subject to periodic review and adjustments over time as our understanding improves and new issues and technological advances arise.

NORTHEAST COASTAL AND BARRIER NETWORK PARK RESOURCES AND ISSUES

Overview of NCBN Parks and Selected Natural Resources

The Northeast Coastal and Barrier Network (NCBN) includes eight parks stretching along the coastline of the Northeastern United States from Massachusetts to Virginia (Table 1). These parks represent some of the most ecologically similar collections of lands within the Park Service. They consist of critical coastal habitat for many rare and endangered species, as well as migratory corridors for birds, sea turtles and marine mammals. They also protect vital coastal wetlands, essential to water quality, fisheries, and the biological diversity of coastal, nearshore, and terrestrial environments.

As part of the Atlantic coastline, parks in the Northeast Coastal and Barrier Network represent islands of protected lands within the urban sprawl of the Northeast. Sixteen percent of the entire United States population resides in the coastal zone (Culliton, *et al*. 1990). Census estimates indicate that populations residing within this zone are growing three times the rate of the total United States population (Culliton *et al*. 1989). Without scientifically based knowledge and information on the effects of urban pressure on the health of these park ecosystems, it is uncertain that current management decisions are being made that maintain or restore ecosystem health in these parks. Developing a long-term monitoring program is fundamental to the protection and management of their natural resources. Key components in developing a structured monitoring program for the Network include data collection, information management, preparation of data summaries and interpretive reports, feedback to park resource management, and program coordination and support.

Detailed descriptions of natural resources and management issues for each park are presented in Appendix 11. An overview of special habitats that occur in each park is included in Appendix 11. The brief park descriptions provided below include a summary of water quality information for each park. This information was compiled as part of a data mining project funded by the Network. The final report (to be available December 2003) will include: (1) a summary of threats, (2) an analysis of how threats are altering structure and function of wetlands within the Network parks, (3) an evaluation of existing monitoring programs with suggestions for improvements, and (4) a summary of information from state 305(b) and 303(d) reports that includes a discussion of Network needs to identify pristine as well as impaired waters in the network (a preliminary report is available now; see Appendix 9).

Table 1. Northeast Coastal and Barrier Network Park Members.

Park Name	Code	State	Hectares	Acreage
Assateague Island National Seashore	ASIS	MD,VA	19,200	48,000
Cape Cod National Seashore	CACO	MA	17,442	43,604
Gateway National Recreation Area	GATE	NY, NJ	10,644	26,610
Fire Island National Seashore	FIIS	NY	7,832	19,580
Colonial National Historical Park	COLO	VA	3,740	9,350
George Washington Birth Place NM	GEWA	VA	220	550
Thomas Stone National Historic Site	THST	MD	129	322
Sagamore Hill National Historic Site	SAHI	NY	33	83

Assateague Island National Seashore (ASIS) encompasses more than 19,000 hectares, more than half of which consists of oceanic and estuarine waters surrounding the Island. Located within a three-hour drive of the Washington/Baltimore/Philadelphia metropolitan area, the National Seashore hosts more than 1.8 million visitors every year. The park's natural resources include a diverse assemblage of aquatic and terrestrial wildlife, including the free-roaming feral horses for which Assateague is famous. The vegetation communities, geological features and physical processes reflect the complexity of the land/sea interface along the Mid-Atlantic coast. The indigenous plant communities at ASIS reflect the adaptive extremes necessary for survival on a barrier island, where exposure to salt spray, lack of freshwater, and shifting sands create a harsh and dynamic environment.

Water Quality Information-ASIS has many salt marsh pools within the island's salt marshes, however there are few, freshwater waterbodies. The majority of wetlands within ASIS receive water from the surrounding Bays, such as Chincoteague Bay. The attainment status for many of the designated uses for waters adjacent to ASIS could not be found, however some of the estuarine bays (Chincoteague Bay, Sinepuxent Bay, Tom's Cove, and Assateague Channel) surrounding ASIS are 303(d) listed. These Bays are impaired by nutrients, low dissolved oxygen, and fecal coliform from non-point and natural sources. Shellfishing is restricted within these Bays.

Cape Cod National Seashore (CACO) preserves approximately 17,442 hectares of uplands, wetlands and tidal lands located on Outer Cape Cod, Massachusetts. A mosaic of natural and cultural resources, which are the result of dynamic natural processes and at least 9,000 years of human activity, characterizes CACO. The natural terrain contains an exceptional array of coastal communities, including pitch pine/oak forest, heathlands (nearly the entire eastern U.S. distribution of heathlands is restricted to fragments on the Outer Cape and in coastal Maine), dunes and coastal plain pond shores. There is also a wide diversity of aquatic and marine habitats, such as kettle ponds, cedar swamps, vernal pools), drowned river valley salt marshes, back barrier salt marshes, barrier spits and inter-tidal mudflats. CACO serves as one of the National Park Services prototype monitoring parks for the Atlantic and Gulf Coast biogeographic region.

Water Quality Information- At CACO only a few of the estuarine waters on the 303(d) list have been assessed, and only for a few uses such as primary and secondary contact recreation and shellfishing. The other designated uses (e.g. aquatic life support, fish consumption, and aesthetics) have not been assessed. Many waters are only noted as having a fish consumption advisory in effect as the Massachusetts Department of Public Health (MADPH) has issued an advisory for both freshwater and marine species due to mercury contamination. Due to this advisory, waters within the Cape Cod watershed cannot be assessed as supporting or partially supporting fish consumption. Of those waters that have been assessed, the primary impairment is pathogens, although acidity and metals have recently been added for one waterbody (Herring River). The main designated use that is impaired is shellfishing for various sections of estuarine waters adjacent to CACO. There are no sources listed for these impairments. Approximately 23% of the freshwater ponds and lakes within CACO are listed as impaired, however only one (Ryder Pond) has been assessed for designated uses. Ryder Pond is impaired by nutrients, organic enrichment, and low dissolved oxygen from unknown sources. This pond supports aquatic life support, and primary and secondary contact recreation, but other designated uses have not been assessed. The MADPH fish consumption advisory applies to this waterbody. It is likely that other ponds may be similarly impaired, however since many of the freshwaters within CACO have not yet been assessed there is no further information.

Waters in and adjacent (within 1,000 feet seaward of mean low water) to Cape Cod National Seashore have been classified as Outstanding Resource Waters (ORW) by the Massachusetts Department of Environmental Protection. However, two of the waterbodies listed as ORW (Herring River and Herring Pond) are also listed on the 2002 303(d) list. Pleasant Bay and Wellfleet Harbor have been designated as an Area of Critical Environmental Concern by Massachusetts Department of Environmental Management. However, Wellfleet Harbor is also 303(d) listed due to pathogens and non-support of shellfishing in Area CCB10.0.

Colonial National Historical Park's (COLO) 3,740 hectares are within the coastal plain of Tidewater Virginia. Most of the park extends along either the York or James Rivers, two of the largest rivers contiguous to the western shore of the Chesapeake Bay. Numerous streams, creeks and ponds flow through the park and feed directly into one of these two rivers. Mixed pine and hardwood forests cover most of the park. The biological resources of Colonial NHP include a variety of birds, fish, mammals, aquatic invertebrates, plants and wetlands typical of the mid-Atlantic Coastal Plain.

Water Quality Information- At COLO, 48% of waterbodies within or adjacent to the park unit are impaired (not including the James or York Rivers). The most common impairments are pathogens (e.g. fecal coliform), Virginia Department of Health shellfish restrictions, organic enrichment, and low dissolved oxygen. However, nutrients, PCBs (in sediments and fish tissue), general benthic standard, and siltation are also problems. Sources include natural, non-point sources, and sediment PCBs (in on waterbody), although sources for a majority of impairments are unknown. Designated uses that are the most greatly affected are aquatic life support, primary contact recreation, and shellfish harvesting. The James River is impaired by nutrients of an unknown source. The York River is impaired for the general benthic standard, organic enrichment, dissolved oxygen, and nutrients from unknown and natural sources. There are no Outstanding Resource Waters within COLO.

Fire Island National Seashore (FIIS) is a barrier island approximately 7,832 hectares in size, located along the southern coast of Long Island, New York. Annual visitation to the National Seashore exceeds 1 million. Approximately 51 km long and averaging about 0.5 km in width, the island is bordered by the inlets of Fire Island to the west and Moriches to the east and is separated from Long Island by the Great South and Moriches Bays. Fire Island is typical of Atlantic barrier islands that grade from a primary dune along the ocean to salt marsh along the bay. Natural resource management at FIIS deals with extremes in land use issues within the park. The only federally designated wilderness in the state of New York and in National Parks of the Northeastern United States is found on eastern Fire Island. On the other hand, seventeen private resort communities comprising approximately 4,000 homes, lie within the administrative boundary of FIIS on the western end of the island.

Water Quality Information- As FIIS is a coastal barrier island, there are few waterbodies within the confines of the Park boundary. The majority of wetlands within FIIS receive water from the surrounding Bays, such as Great South Bay. All coastal Bays adjacent to FIIS are impaired by pathogens from urban and storm runoff, but agriculture runoff is also a source. The pathogens primarily impact the designated use of shellfishing in all Bays adjacent to FIIS. Information on Outstanding Resource Waters could not be found for the state of New York.

Gateway National Recreation Area (GATE) is 10,644 hectares of coastal uplands, freshwater ponds, marshes, bays and mudflats. The park is divided into three geographically separate units that constitute some of the largest and most significant natural areas remaining in the metropolitan New York City area. They include the Jamaica Bay/Breezy Point Unit which is the entire Jamaica Bay estuarine lagoon, part of Rockaway Inlet, and the western part of the Rockaway barrier beach. The boundary of this area generally follows the shoreline of Jamaica Bay and includes most of the tidal creeks and undeveloped upland areas adjacent to the bay. The Staten Island Unit include large areas of disturbed common reed marsh with grassland and shrub thicket at Crookes Point. The outer shoreline follows a narrow, sandy, groined beach. A large area of flats in Great Kills Harbor extends southwest along the Staten Island Shoreline. The Staten Island complex include shallow estuarine open waters, sandy beach, maritime forest, salt marsh, mudflats, and riparian forest. These habitats support a large number of regionally rare and important species. Sandy Hook separates the Atlantic Ocean from the southern portion of the New York - New Jersey Harbor Estuary and serves as a dividing line between certain groups of species, with marine, estuarine, and anadromous species concentrated on the outside, shorebirds and waterfowl concentrated on the inside, and migratory landbirds (raptors and passerines) concentrated on the peninsula itself. It is the only undeveloped barrier beach area on the northern end of the New Jersey coastline north of Island Beach State Park, located 55 kilometers (34 miles) to the south. Its sandy shorelines and backdunes provide germination and breeding habitats for a variety of threatened, endangered and rare species of flora and fauna. Maritime holly forests that occur at Sandy Hook occur at only a few other locations in the region and are a globally imperiled community due to their rarity.

Water Quality Information- The waterbodies within GATE consist of bays or harbors adjacent to the Park Units. Waterbodies within the Jamaica Bay Unit of GATE are impaired primarily by pathogens, low dissolved oxygen, organic enrichment and nitrogen. Sources of these impairments are from combined sewer overflows, urban and storm runoff, and municipal wastewater systems. Uses that are impacted are shellfishing, fish consumption and propagation, and bathing which are either partially supported or not supported for these activities. Contaminated sediments are a problem in Ridder's Pond (pesticides and chlordane contamination) which impair fish consumption. In Lower New York Bay, which borders the Staten Island Unit of GATE, consumption of migratory fish species is impaired due to PCB's and pathogens from combined sewer overflows. Shellfishing is partially supported in Sandy Hook Bay, the waterbody adjacent to the Sandy Hook Unit of GATE. Fecal coliform, low dissolved oxygen, chromium, copper lead, and mercury from unknown sources are contaminates in this waterbody. Information on Outstanding Resource Waters could not be found for the state of New

York (GATE-Jamaica Bay and Staten Island Units). There are no Class FW1 or PL (Outstanding Resource Waters) waters within the Sandy Hook Unit of GATE.

<u>George Washington Birthplace National Monument (GEWA)</u> is located on the northern neck of rural and tidal Virginia. The park consists of 220 hectares along the tidal reaches of the Potomac River. The park is fairly flat, typical of the coastal plain. Bounded by the Potomac at the north, three small sub-basins drain into the Potomac at GEWA. These are Pope's Creek, Bridges Creek, and a third unnamed creek. Salinity of Pope's Creek and other marshes within the park can be as much as 60% sea water with crabs, jellyfish, oysters and other marine organisms present. The natural resources in the park include mixed conifer/hardwood forest and loblolly plantations, open fields, fresh and saltwater marshes and swamps.

<u>Water Quality Information</u>- The only waterbody within GEWA that is listed as impaired is Pope's Creek which comprises 99% of the Park's waterbodies. Pope's Creek has a Virginia Department of Health shellfish restriction and is impaired by fecal coliform and pathogens resulting from point and non-point sources, and partially supports shellfishing and primary contact recreation. GEWA is also adjacent to the Potomac River which is impaired by organic enrichment, low dissolved oxygen, suspended sediment, and pathogens resulting from enrichment, natural, and non-point sources. The Potomac River has a fish consumption advisory in effect as it partially supports fish, shellfish, and wildlife protection and propagation. There are no Outstanding Resource Waters within GEWA.

<u>Thomas Stone National Historic Site (THST)</u> is located about 32 km south of Washington D.C the park is comprised of 130 hectares of hilly lands that drain into the Hoghole Run, emptying into the Port Tobacco Creek south of the park boundary. Natural resources in the park include wetland, mixed forests and fields. Few biological inventories have been done at THST so there currently are large gaps in knowledge about the existing natural resources in the park. Over the past couple of years due to the Natural Resource Challenge, implementation of vertebrate and vascular plant inventories has begun in the park. In 2001, a vegetation classification and mapping project was initiated at THST a sedge species was found and collected in the park of the genus Carex that did not match known species for the state, even following comparisons with specimens in herbaria. This species was recognized as a species that was undescribed. Thus, the sedge found at Thomas Stone NHS will contribute to the description of a species new to science and also represent the first known Maryland occurrence of it.

<u>Water Quality Information</u>- There are only a few small unnamed ponds and streams within THST, none of which are listed as assessed or impaired. The Port Tobacco River, which is approximately 1.5km from the Park, is impaired by nutrients from non-point and natural sources, but the non-tidal portion of the river is not 303(d) listed and no designated uses are impaired for this portion of the river. Information on Outstanding Resource Waters could not be found for the state of Maryland.

<u>Sagamore Hill National Historic Site (SAHI)</u> was the home of Theodore Roosevelt located on the peninsula of Cove Neck, Long Island, New York. In 1883 Roosevelt purchased farmland with shoreline on both Oyster Bay and Cold Spring Harbor. He quickly sold off some of the property facing Oyster Bay to relatives, and built a large country home on the top of a hill with views across the water. Farm fields gave way to an oak-chestnut-tulip forest running down to a salt marsh that opens to Cold Spring Harbor. His family eventually sold off more acreage until it reached its current size of 35 hectares. Today the farm has given way to visitor facilities including a parking lot and visitor center (0.8 hectares combined), paved driveways, and mowed lawns (4 hectares). There remains about 4.8 hectares of rough fields. The forest of about 20 hectares has matured despite the loss of the chestnuts to the blight. The easternmost forested and saltmarsh area of the park were declared a "Natural

Environmental Study Area" by Congress in the early 1970's. The 4 hectare Eel Creek saltmarsh is an excellent example of the tidal saltmarshes that once lined the shore of Long Island.

Water Quality Information- SAHI has only one, small (2 ha) wetland that is fed by a tidal creek that receives water from Cold Spring Harbor. The impairments to Cold Spring Harbor are pathogens and PCBs in migratory fish species from urban and storm runoff. The designated uses of shellfishing and fish consumption are not supporting by Cold Spring Harbor waters. Information on Outstanding Resource Waters could not be found for the state of New York.

Natural Resources Significant to enabling Legislation and Legal Mandates

In order to identify significant natural resources in the network, each park's enabling legislation and planning documents were reviewed. Table 2 provides a list of natural resources summarized from each park's enabling legislation as well as natural resources significant to other federal legal mandates. Natural resources are specifically mentioned in the enabling legislation of four network parks: Assateague Island National Seashore, Cape Cod National Seashore, Fire Island National Seashore and Gateway National Recreation Area. Although natural resources are not mentioned in the enabling legislation of the other four parks, certain resources are significant because of the interpretation of the historic landscapes (e.g., field, forest, salt marsh, beach, wetland, and rivers). Parks such as George Washington Birthplace National Monument and Sagamore Hill National Historic Site, are concerned with preserving the natural viewshed from park historic buildings.

FIIS, GATE, ASIS and CACO have specific protection and responsibilities under Executive Order 13158-Marine Protected Areas (MPA). This order defines an MPA as "any area of the marine environment that has been reserved by Federal, State, territorial, tribal or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (Federal Register 2000). MPAs will be used as management tools to protect, maintain, or restore natural and cultural resources in coastal and marine waters. They have been used effectively both nationally and internationally to conserve biodiversity, manage natural resources, protect endangered species, reduce user conflicts, provide educational and research opportunities, and enhance commercial and recreational activities (Salm *et al*. 2000).

Five parks in the NCBN have federally listed species, both plants and animals. Four of the parks, ASIS, CACO, FIIS and GATE having the federally endangered, beach nesting piping plover. COLO, ASIS and GEWA have nesting bald eagles.

Table 2. Legislative guidance for Vital Signs monitoring in the Northeast Coastal and Barrier Network parks.

Park	Natural Resources identified in Park Enabling Legislation	Natural Resources Significant to Other Federal Legal Mandates
ASIS	Assateague Island and adjacent waters and small marsh islands. Conservation of natural features contributing to public enjoyment. Hunting, fishing, and shellfishing permitted in accordance with State laws, provided that Federal laws regulating migratory waterfowl are not added to or limited. The Secretaries of the Interior and Army shall cooperate in the study of plans for beach erosion control and hurricane protection.	**Endangered Species Act -** Piping plover(LE),Least tern (PS), Bald eagle(LT). **Marine Mammal Protection Act - Various species. Executive Order 13158 - Marine Protected Areas.**
CACO	Lands and waters out to a quarter of a mile offshore. No development or plan incompatible with the preservation of the unique flora and fauna and physiographic conditions shall be undertaken. Hunting and fishing permitted under State and Federal jursidiction, and shellfishing permitted under State and town jurisdiction.	**Endangered Species Act** - 17 listed animal species, including piping plover. **Marine Mammal Protection Act** - Various species. **Executive Order 13158 - Marine Protected Areas.**
COLO	None Identified	**Endangered Species Act** - Bald eagle(LT), sensitive joint-vetch (LT), Small whorled pogonia (LE)..
FIIS	Undeveloped beaches, dunes, and other natural features. Sunken Forest shall be preserved from bay to ocean. No development shall be undertaken between Brookhaven town park at Davis Park and Smith Point County Park which would be incompatible with the preservation of the flora and fauna or the physiographic conditions. Hunting, fishing and shellfishing permitted in accordance with State and Federal laws. Shore erosion or beach protection measures shall be exercised with a plan acceptible to the Secretaries of Interior and Army.	**Endangered Species Act -** Piping plover (LE), Roseate tern(PS), Least tern (PS),seabeach amaranth (LT). **Marine Mammal Protection Act - Various species. Public Law 96-585,** December 23, 1980 designated 1363 acres of parkland, located between Smith Point and Watch Hill as a National Wilderness area.
GATE	Lands, waters, marshes and submerged lands, including all islands, marshes, hassocks, submerged lands and waters of Jamaica Bay and Floyd Bennett Field. The Jamaica Bay Unit shall be administered and protected with the primary aim of conserving the natural resources, fish, and wildlife. Hunting, fishing, shellfishing, trapping, and taking of specimens are permitted according to Federal and State laws.	**Endangered Species Act -** Piping plover (LE), Peregrine Falcon (LE), seabeach amaranth (LT); Least tern (PS), Roseate tern(PS). **Executive Order 13158 - Marine Protected Areas.** .
GEWA	None Identified	**Endangered Species Act** - Bald Eagle(LT)
SAHI	None Identified	None Identified
THST	None Identified	None Identified

Natural Resources Identified in Network Park General and Resource Management Plans

Both general and resource management plans were reviewed for the network parks. Tables 3 and 4 below summarize the significant natural resources identified by each park in these management plans. Table 5 (In development) will include natural resource issues identified in each park's strategic plan. Because the coastal parks exhibit a high degree of physical and biological similarity, it is not surprising that similar ecosystem types and related issues have been identified across park plans. Significant ecosystem types in the coastal parks include:

- Shoreline/Barrier Beach and Dune (Mentioned in all NCBN park GMP's or RMP's except THST)
- Salt marsh (Mentioned in all NCBN park GMP's or RMP's except THST)
- Estuary (Mentioned in all NCBN park GMP's or RMP's except THST and SAHI)
- Coastal Upland (Mentioned in all NCBN park GMP's or RMP's.)
- Freshwater wetlands (Mentioned in all NCBN park GMP's or RMP's)

Repeating issues found in NCBN park's GMP/RMP's include:

- Exotic plants and animals
- Water quality
- Eutrophication
- Visitor use
- Resource consumption
- Shoreline processes/shoreline erosion
- Deer population manangement
- Protection of rare, threatened and endangered species
- Air quality
- Viewshed
- Woodland preservation

Table 3. Summary of Northeast Coastal and Barrier Network Parks General Management Plans.

Park	Natural Resources and Natural Resource – Related Goals from General Management Plans
ASIS	**(1982) Resources:** Barrier beach and dune system. Beach grass, shrub thicket, wetland forest, and salt marsh communities. Wetland plants in impoundments. Assateague pony, peregrine falcon, Delmarva fox squirrel, osprey, eastern merlin, Ipswich sparrow, and Atlantic loggerhead turtle. Dynamic physical and ecological processes and natural succession. **Plan Goals:** Management of exotic plants and animals. Assateague ponies managed as a desireable feral species. Visitor-operated vehicles limited to certain zones and for certain purposes. Collaborate on implementing a plan to slow, stop, or reverse the shoreward erosion of northern Assateague Island. Protection of habitats of endangered flora and fauna. Maryland upland game hunting will continue. In some areas dune breaks and crossings will be repaired or maintained. Beach recreation, fishing, clamming, crabbing, mussel gathering, canoeing and wildlife observation will be permitted. Back country campsites will be maintained.
CACO	**(1998) Plan Goals**: Engage in cooperative regional efforts to improve air quality. Allow natural shoreline processes to take place unimpeded. Protect ground and surface water quality and quantity, as well as wetlands. Upgrade septic treatment facilities to reduce nitrates. Correct runoff point sources. Develop resource management plans for all kettle ponds. Research and monitor effects of aquaculture on marine resources. Restore the natural hydrography and ecology of estuaries in consultation with affected municipalities (including Herring River salt marsh, Pamet River, and Pilgrim Lake areas). Manage native biotic resources by allowing natural processes to continue unimpeded except where appropriate to selectively manage for native biological diversity or rare species or communities. Utilize fire management to restore or simulate natural role of fire. Develop management plans for heathlands. Restore native habitats and disturbed areas. Develop non-native species management program. Review and permit finfish and aquatic plant aquaculture based on strict conditions. Develop a comprehensive pest management program.
COLO	**(1993)** Note – partial review, confirmation needed. **Resources:** Chesapeake Bay, James and York Rivers, and tributaries. Tidal salt water and estuarine wetlands, freshwater wetlands. Coastal plain sediments. Federally listed bald eagle and several state listed flora and fauna species. Hardwood and pine-hardwood forests, salmarsh and freshwater wetland vegetation. Submerged aquatic vegetation. **Plan Goals:** Protect rare, threatened, and endangered species by developing sub-zones within historic zones for protection and management. Protect wetlands and floodplains. Limit disturbance in upland areas. Develop inventory and database of natural resources. Develop an active resource monitoring program. Cooperate with other agencies and landowners to promote resource preservation.
FIIS	**(1977) Resources:** Dune line fringing beach. Freshwater bog habitats. Tidal marshes. Skirted Pine Fire Island Lighthouse tract (salt spray influenced vegetation). Sunken Forest. Maritime forest at Point O'Woods. Old Inlet dunes and marsh. High marsh area south of Hospital Island. Watch Hill interpretive area. Clam pond area coves and marshes. Nesting common tern habitat on John Boyle Island. Tidal marshes, swamps, and ponds on Floyd Estate. **Plan Goals:** Protect natural resources of beaches and dunes, maritime holly forests of the Sunken Forest, and experimental marsh adjacent to Barrett Beach. Maintain water quality of Great South Bay and aquifers underlying Fire Island area. **"Update GMP" PMIS statement[1] (2001) Issues:** Shoreline erosion, including in Otis Pike High Dune Wilderness. Deer population management. Insect borne pathogens including Lyme Disease, Eastern Equine Encephalitis, and West Nile virus. Five rare plant and animal species including plovers and terns. Water quality in Great South Bay.

Table 3 (Cont.). Summary of Northeast Coastal and Barrier Network Parks General Management Plans.

Park	Natural Resources and Natural Resource – Related Goals from General Management Plans (Continued)
GATE	**(1979) Resources:** Holly forest at Sandy Hook. High and low salt marshes, primary dunes, freshwater marshes, and beach heather communities. Waterbird nesting sites. **Plan Goals:** Identify, preserve, and provide for visitor appreciation of fish, wildlife, and other natural resources. Protect holly forest at Sandy Hook. Protect wildlife refuge in Jamaica Bay. Improve air and water quality. Minimize air and water pollution in Jamaica Bay. Protect tern nesting sites. Employ habitat management techniques to protect wildlife, including migratory bird and butterfly species. Study phragmites role in the marsh ecosystem. Employ biological control of ticks, mosquitos, green flies etc... wherever possible.
GEWA	**From Statement for Management[2] (1986) Goals:** Secure through research, or other means, adequate information to facilitate information and perpetuation of the Pope's Creek Farm and other historical and natural resources. Preserve...the quality of natural scenes.
SAHI	GMP planning in process.
THST	**(1989, Revision 1996) Resources:** Coastal plain geology and soils. Many springs and three ravines cut by intermittent streams, draining to Hoghole Run. Palustrine non-tidal freshwater wetlands, including farm pond, forested wetland, and emergent wetland. Mixed hardwood and pine forests with regionally representative shrub understory. Oak decline syndrome. Beaver, white-tail deer, and Bluebirds. Gypsy moths. Ticks and Lyme disease. Class 2 air quality area. **Plan Goals:** Manage and protect the natural resources of the site consistent with the need to interpret agrarian lifestyles and re-establish historic landscapes. Provide appropriate wildlife habitat and preserve the existing wooded areas to prevent further erosion of the ravines and streambeds. Improve the quality of surface water that enters Hoghole Run. Restore pond areas to natural and historic condition.

Notes:
[1] - Project Management Information System, a database used to track projects throughout the NPS.
[2] - Statements for Management are used by the National Park Service to identify the guiding management priorities for parks.

Table 4. Summary of Northeast Coastal and Barrier Network Parks Resource Management Plans.

Park	Natural Resources Identified in RMP	Natural Resources Related Issues from RMP	NR Related Management Objectives from RMP
ASIS	**(1993)** Freshwater ponds, saltmarsh wetlands, tidal mudflats, seagrass beds, and open water habitats. Assateague pony. Sika deer. Tundra peregrine falcon, loggerhead sea turtle, Delmarva fox squirrel, and piping plover. Wintering waterfowl populations, reptiles and amphibians, and marine mollusks. Submerged aquatic vegetation. Marine finfish, shellfish, and benthic invertebrates. Freshwater fish and invertebrates. Phragmites.	Artificial dune systems preventing overwash processes. Past development activity. Remnant roadbeds and mosquito control drainage ditches. Disruption of natural coastal processes outside the Seashore's boundaries. Assateague pony herd influence on vegetation. Sika deer competition with the native white-tailed deer. Recreational visitor use impacts on shorebirds, including plovers. Loss of wetlands and submerged habitats. Marine and estuarine impacts from dredging, motor vessel use, fisheries, increased nutrient input, increased surface water runoff, and contamination by toxic elements. Changes in local/regional land use practices. Limited information on algae, liverworts, mosses, lichen, and fungi.	Development of management strategies including fire management, exotic species, ORV use, dune management, adjacent land use, and especially feral pony herd management and island dynamics at the North End. Development of a comprehensive monitoring plan. Restoration of impacted resources, emphasizing species of special concern, mitigation of visitor use and external impacts, and the reversal of past management and land use practices.
CACO	**(1999)** Terrestrial resources include pitch pine/oak forest, heathlands, dunes, coastal plain pondshores and barrier spits. Aquatic resources include sole source aquifer, kettle and dune ponds, streams and rivers, freshwater marshes, sphagnum and cranberry bogs, red maple and white cedar swamps, vernal ponds, brackish impoundments, intertidal salt marshes, mud and sand flats, eelgrass and marine algae beds, rockweed and barnacle communities, and open marine waters. 32 state listed plant species (none are federally listed). 14 federally listed wildlife species and an additional 58 state-listed species. Non-native plant and animal species.	Impacts of development on water quality and quantity. Accelerated rates of freshwater and coastal marine eutrophication. Impacts of recreation on natural resources. Effects of landscape changes since European settlement. Protection and restoration of federal and state listed rare species and communities. Consumptive uses of resources. Air pollution. Sea level rise.	Allow natural shoreline processes to take place unimpeded. Protect ground and surface water quality and quantity. Restore natural hydrography and ecology of estuaries. Manage native biotic resources. Manage special uses affecting wildlife populations and other biotic resources. Engage in cooperative regional efforts to improve air quality. Implement comprehensive and long-term program of ecological monitoring and research.
COLO	**(1999)** Review pending.	Review pending.	RMP not reviewed. The following is from secondary sources: Preserve, protect and interpret natural resources and processes. Protect rare species. Conduct research and monitoring to guide decision making. Develop park facilities and operations in such a way as to avoid resource damage.

Table 4 (Cont.). Summary of Northeast Coastal and Barrier Network Parks Resource Management Plans.

Park	Natural Resources Identified in RMP	Natural Resources Related Issues from RMP	NR Related Management Objectives from RMP
FIIS	**(1998)** Tidal ponds at Floyd Estate. Fresh and brackish water ponds. Category 2 air quality region. Primary dune, swale, secondary dune, maritime forest, fresh water marsh/bogs, and salt-water marsh vegetation communities. Beach amaranth. Piping plover, gulls, terns, osprey, northeast beach tiger beetle, and eastern mud turtle. Pest species - Norway rat, wood boring insects, gypsy moth, mosquitoes.	Encroachment into Park lands. Water quality in Great South Bay, ocean bathing beaches, and ocean and bayside beaches. No method of obtaining pollution information. Weather stations require funding for maintenance to be used. Wildlife distribution and impacts. Dominance of exotic species on Fire Island is not being studied sufficiently. Phragmites continues to increase in the Wilderness area marsh. Impacts of wildlife browsing and plant dominance on Sunken forest plant communities. Need for biological technicians with a natural resource background for inventory and monitoring. Lyme disease. Turbidity impacts to flora and fauna along the bayside shore. Pollutant impacts to the bayside ecosystem from marinas. Impacts of home bulkheading and scraping on dunes. Aircraft overflight noise in wilderness area.	Survey, determine, and mark Seashore boundaries. Complete IPM and Fire Management Plans. Control autumn olive and tree of heaven at Floyd Estate. Survey recreational and commercial fishing. Clarify the condition and impacts of fresh water ponds. Implement sustained geologic resources monitoring program for dunes. Develop an Inventory and Monitoring program for park vegetation. Plan habitat restoration activities following protection of vehicle free areas and rare species research. Monitor human disturbance of rare species habitat and mitigate. Monitor visibility by photo-documentation.
GATE	**(1992)** Ecology Village Pine Forest. Jamaica Bay ponds. Staten Island breeding birds, aquatic invertebrates and freshwater wetlands. Sandy Hook ponds. Great Kills salt marsh peat. Rare plants including seabeach amaranth and seabeach knotweed. Osprey. Cavity nesting birds. Grassland bird habitat. Swamp white oak forest. Exotic plants.	Jamaica Bay estuarine and terrestrial impacts from landfill contaminants. Vegetation impacts by vehicles.	None identified.
GEWA	**(2000)** Open fields and forests. Historic trees approaching 200 years in age. Fresh water and brackish marshes, estuaries, three freshwater ponds. Beach and dune assemblages. Hydric and non-hydric soils. Bald eagles. Wintering waterfowl. White-tail deer. Pope's and Bridge's Creeks. Gypsy moth. Phragmites.	Air quality threats are likely to increase. Oil leases are potential water quality threat. Concern about aquifer water quantity.	Manage habitats to achieve greatest health and diversity and to allow for the reintroduction of native species that should be present, including managing for non-native species.
SAHI	**(1992)** Open fields. Woodlands. Two glacial ponds. Marsh. Beach.	None identified.	Develop baseline information on natural resources.
THST	**(1992)** Wildlife and plants typical of a Southern Maryland wooded area. Eastern bluebirds. Several small streams empying into Hoghole Run. One spring-fed pond.	None identified.	Maintain wildlife habitat by preserving the existing wooded areas to prevent further erosion of the ravines and streambeds.

Table 5. **NOTE**: Table in development-Summary of Northeast Coastal and Barrier Network Parks GPRA Goals.

Identification of Important Management and Scientific Issues for NCBN Parks

Before sufficient funding became available through the Natural Resource Challenge in 2000, the Northeast Field Area of the National Park Service began to develop a strategy for the long-term protection of natural resources and ecosystems in the region's parks. Over a number of years, both USGS and NPS workshops and symposia were held to discuss the need for ecological monitoring in these parks. Athough these workshops included parks outside the more recently established I&M Program Northeast Coastal and Barrier Network, a number of the network parks participated.

One of the first planning workshops was held in September 1997. The Region held a two-day, inventory and monitoring workshop at the Patuxent Wildlife Refuge Visitor Center in Laurel, Maryland. Ten parks participated, including four NCBN parks (ASIS, FIIS, GATE and CACO). The workshop title was, *Developing a Conceptual Design for a Multi-park, Long-term Monitoring Program in the Northeast Field Area, National Park S*ervice. The purpose of this workshop was to develop a Northeast field area-wide ecological monitoring strategy.

Prior to this workshop, each participating park was tasked with developing a "laundry list" of natural resource related management issues for discussion. Although many issues were addressed, the following is a list of issues identified during the workshop, common specifically to all four NCBN parks:

- Adjacent land development
- Accelerated estuarine nutrient enrichment
- Increasing visitor use and recreational impacts
- Shoreline change
- Rare species-protection
- Water quality
- Exotic species impacts

In 1999 as part of the USGS Patuxent Annual Science Meeting, a symposium was organized called *Coastal Issues and Information Needs*. Internationally recognized leaders in coastal ecology joined forces with DOI coastal land and resource managers to identify key scientific issues, information gaps, and long-term data needs relevant to coastal resource management. Similar to the 1997 workshop, the management issues identified during this meeting were similar across the coastal parks and included adjacent land development, estuarine water quality and nutrient enrichment, increasing visitor and recreational use and their impacts, shoreline erosion and exotic species (Appendix 12).

In February 2000, as part of another Patuxent Wildlife Research Center annual science meeting, another workshop was held, titled *Developing a Scientific Basis for Integrated Long-Term Monitoring of Atlantic Coastal Parks and Refuges*. The workshop objectives included identifying indicators for long-term monitoring that provide quantitative information on coastal ecosystem functions and identifying threshold values for coastal ecosystem indicators that denote sustainable vs. degraded systems (Appendix 13).

Unfortunately, the lack of funding prior to the NPS Natural Resource Challenge limited the implementation of the plans and ideas discussed at these symposia and workshops. Once full funding became available in 2000, and the National Inventory and Monitoring Program was implemented, the Northeast Coastal and Barrier Network (one of the first networks to receive monitoring funds) was significantly ahead in designing a long-term monitoring program due to the previous work done in the region by NPS and USGS scientists. Significant ecosystems and issues had been identified for most of the coastal parks. A number of common issues had been repeatedly discussed and prioritized for monitoring in these parks, specifically, shoreline change, estuarine nutrient enrichment, and visitor impacts.

Coastal ecosystems, and scientific and management issues of concern to natural resource stewardship in the NCBN parks are summarized in Tables 6 and 7. The information in these tables was compiled through the review of park GMPs and RMPs, park enabling legislation, information compiled from the NPS and USGS workshops mentioned above, and questionnaires sent to each park resource manager and superintendent requesting information on specific park natural resource management issues and significant ecosystem types. These questionnaires were developed and sent to the parks prior to the Network's Vital Signs Scoping Workshop held at Gateway National Recreation Area in April, 2000. The Vital Signs Workshop is discussed in further detail in Chapter 3 of this plan. NCBN park ecosystems and issues are further described in Chapter 2: Conceptual Ecological Models, and in Appendix 14.

Table 6. Northeast Coastal and Barrier Network significant scientific and management issues.

ISSUE	**CACO**	**FIIS**	**SAHI**	**GATE**	**ASIS**	**THST**	**GEWA**	**COLO**
Altered coastal processes	X	X			X		X	X
Accelerated rates of erosion due to recreational impacts dredging/deposition of spoil	X							
Sea level rise	X							
Shoreline Change	X	X			X		X	X
Inlet migration	X							
Changes in lateral sand transport due to dredging and groins		X			X			
Impacts on biota due to dredging of channels/inlets		X		X	X			
Dune habitat characterization							X	
Altered coastal processes impacts on early successional, disturbance driven beach habitat and assoc. plant/animal species					X			
Visitor/Recreational Activity Impacts	X	X			X			X
Social trails/trampling of vegetation/mountain bike trails	X	X						
Jet Skis	X	X						
Pets off leash/hunting dogs	X							
Releasing non-native pheasants for put/take hunting	X							
Recreational trampling of kettle pond	X							
Visitor impacts/activities on R,T,E species		X			X			X
Visitor impacts on other plant or animal species					X			
Recreational activity impacts on early successional, disturbance driven beach habitat and assoc. plant/animal species	X	X			X			
Recreational impacts on bluffs	X							X
Off-road vehicle use in park					X			
Increased human activity/disturbance within park due to increased residential development adjacent to park	X							

Table 6 (Cont.). Northeast Coastal and Barrier Network significant scientific and management issues.

ISSUE	**CACO**	**FIIS**	**SAHI**	**GATE**	**ASIS**	**THST**	**GEWA**	**COLO**
Water Quality Within Park	X	X		X			X	X
Identification and assessment of water quality issues	X						X	
Water quality due to adjacent land use	X	X		X			X	X
Due to Residential development	X							
Due to Urban development							X	X
Due to Agricultural development							X	X
Groundwater	X							X
Groundwater withdrawal from adjacent or within residential development and impacts to wetland vegetation and animal life	X							
Assess potential groundwater contamination								X
Are there impacts to groundwater from landfill leachates	X							
Nutrient Enrichment	X			X				
Septic inputs from residential development within or adjacent to park	X			X				
Industrial effluent				X				
Cultural nutrient enrichment of Kettle Ponds and Salt Marsh	X							
Freshwater and Coastal Marine Eutrophication	X			X				
Estuarine Water Quality	X	X		X	X		X	X
Adjacent land use changes associated with estuarine water quality	X			X	X		X	X
Urban							X	X
Residential	X							
Agricultural							X	X
Decline (loss) of Submerged Aquatic Vegetation					X			X
Impacts on aquatic resources from channel and marina dredging and pollution from community marinas unknown		X						
Changes in associated biotic communities					X			
Impact of landfill leachate	X							
Impacts on estuarine water quality due to shoreline erosion							X	
Wildlife Management	X	X	X	X	X	X	X	X
Factors contributing to decline in species abundance	X	X						
Lack of status and distribution data on formerly common species	X							
Lack of baseline studies for most non-RTE species	X					X		
Habitat impacts from deer population						X	X	
Habitat impacts from woodchuck population							X	
Neotropical migrant use of park habitats				X				
Bird aircraft collisions				X				
Beach nesting bird predators/impactors				X				
Habitat management for grassland birds				X				
Preservation of Native species biodiversity	X						X	
Rare, Threatened and Endangered Species Protection and restoration (Vertebrates)	X	X			X	X	X	X
Document species composition, distribution, abundance and any rare, threatened, or endangered species.			X		X	X	X	
Impacts of hunting and power line right of way on species						X		

Table 6 (Cont.). Northeast Coastal and Barrier Network significant scientific and management issues.

ISSUE	**CACO**	**FIIS**	**SAHI**	**GATE**	**ASIS**	**THST**	**GEWA**	**COLO**
Impacts of Residential/Urban development within and adjacent to park	X							
Impacts on vertebrate populations due to increases in road kill	X			X				
Impacts on vertebrate populations due to habitat fragmentation	X			X				
Impacts on vertebrate populations due to increased pet predation on native wildlife	X			X				
Impacts of increased human disturbance on wildlife				X		X		
Exotic/Invasive Species	X	X	X		X	X	X	X
Plants	X	X			X			X
Animals					X			X
Rare/sensitive habitats at risk from exotic species					X		X	X
Lack of distribution, abundance and impacts on native biota and physical processes	X		X			X	X	
Loss of grassland/heath land habitats and associated wildlife	X							
Habitat Loss								
Salt marsh loss	X			X				
Habitat Restoration		X				X	X	
Historic diking of Salt Marshes and need for restoration	X							
Best action plans for salt marsh restoration		X						
Estuary restoration							X	
Forest							X	
Field						X	X	
Resource Extraction/Harvest	X	X						
Horseshoe crab/crab extraction	X	X					X	
Shellfishing Impacts	X	X						
Hunting Impacts	X	X				X	X	
Fishing Impacts	X	X					X	
Fruits and Fungi	X							
Vascular plants			X				X	
Document species composition, distribution, abundance and any rare, threatened, or endangered species						X	X	
Native grass species reintroduction							X	
Impacts of landscape alteration by Europeans over 4 centuries	X							
Loss of plant species due to shoreline erosion							X	
Protection of R,T,E vegetative species			X				X	
Habitat health-forests, freshwater marsh, riparian zones and salt marsh						X	X	
Air pollution	X	X						
Lack of knowledge regarding air quality		X						
No particulate and SO2 monitoring	X							
Impacts to Aesthetic Resources-Aesthetic concerns include structures, bulkheads, groins, beach scraping and barrier island uses		X						
Human Health	X	X						
Mosquito management	X							
OWMM usefulness in decreasing mosquito populations		X						
Rabies vectors				X				

Table 7. Northeast Coastal and Barrier Network significant ecosystem types.

Ecosystem Type	CACO	FIIS	SAHI	GATE	ASIS	THST	GEWA	COLO
Salt Marsh/Tidal Flats	X	X	X	X	X		X	X
Heathlands	X							
Coastal Grasslands	X					X	X	
Kettle Ponds	X							
Vernal Ponds	X	X	X	X	X	X	X	X
Red Maple swamps	X					X	X	X
White Cedar swamps	X							
Hardwood forests			X	X		X	X	X
Maritime Holly Forest		X		X				
Eel-grass beds	X	X	X	X	X			X
Riparian				X		X	X	X
Beach	X	X	X	X	X		X	X
Dunes	X	X		X	X		X	
Freshwater wetlands	X	X	X	X	X	X	X	X
Estuaries	X	X	X	X	X		X	X

EXISTING MONITORING AND POTENTIAL PARTNERSHIP OPPORTUNITIES FOR NETWORK PARKS

Extensive reviews of existing monitoring programs both occurring within the NCBN parks, locally or regionally in relation to the parks, was conducted by Network staff and cooperators in order to better understand what has historically been done and what is currently or recently been monitored in and around the coastal parks. The results of these reviews from network cooperators and staff, were compiled into one summary table (Appendix 15). The full documents can be found as the following appendices:

Appendix 1--CACO Conceptual Framework_Roman_Apr 1999
Appendix 6--NCBN Phase I Report_Oct 2002.
Appendix 9--Wetlands Water Quality Preliminary Report_JamesPirri_May 2003
Appendix 10--Estuarine Nutrients Report_Neckles_Sep 2002
Appendix 14--Vital Signs Workshop Report_Apr 2000
Appendix 16--CACO Salt Marsh Nekton Protocol_Raposa_Dec 2001
Appendix 17--CACO Salt Marsh Vegetation Protocol_Roman_Dec 2001
Appendix 18--Geomorphology Workshop Report_Duffy_ Oct 2002.
Appendix 19--Inventory Study Plan_Stevens_2002
Appendix 20--Review of Vertebrate Monitoring_Fabre_Jan 2003
Appendix 21--Visitor Impact Phase I_Monz_Mar 2003

CHAPTER 2 NCBN CONCEPTUAL MODELS

INTRODUCTION

Conceptual Models and the development of an ecological monitoring program

Conceptual models are important throughout all phases of development of any monitoring program. They are particularly important in the development of a network-wide, multi-park ecological monitoring program in that they can help provide focus and consensus on many complex issues and major ecosystem components associated within a group of parks. Ecological monitoring programs often fail to formulate meaningful monitoring strategies due to a lack of clarity of purpose and expectations. Conceptual models provide a framework to progress from general monitoring questions to more specific questions (Gross, 2003).

As tools used to assist with the development of a monitoring program, conceptual models can:

- provide organizational focus to large amounts of information; and
- provide communication and consensus among program developers, scientists and park staff.

As tools for understanding ecological complexity, conceptual models can:

- help simplify and clarify complex relationships among ecosystem components; and,
- provide some insight into cause and effect of one ecosystem component vs another, or influences outside the ecosystem and their effects.

The objective in developing conceptual models is to identify the physical and biological components and linkages in an ecosystem, which best describe the:

- major external activities or processes that influence the natural system; the
- associated problems or products of human activities or natural events that alter the quality or integrity of the ecosystem; and the,
- detectable changes that are in any measurable value of the ecosystem structure, function, or process.

Models are not intended to represent a comprehensive account of the entire ecosystem, nor merely a list of mechanisms and outcomes as features of ecosystem change. Conceptual models are used to present a conceptual framework to help select and develop monitoring protocols. While some models may understate the comprehensive nature of ecosystems; they serve to demonstrate the complexity of ecosystem relations, many of which are unknown (Roman and Barrett 1999; Appendix 1).

Types of Conceptual Models

The two most commonly used conceptual model structures are called *control models* and *stressor models.* Control models simulate feedbacks and elementary connections between system components, and more clearly communicate the links between *agents of change, stressors* and *ecosystem responses.* Stressor models typically do not represent feedbacks and they include only a very selective subset of system components (Gross, 2003). The intent of the stressor model type is to illustrate major external activities or processes (Agents of Change) that in some way affect an ecosystem, their associated problems (Stressors) and Ecosystem Responses. It is important to remember that linkages within conceptual models can be presented in a variety of ways, and that one conceptual model is not necessarily more correct than another.

Conceptual models can take the form of any combination of narratives, tables, matrices of factors, or box-and-arrow diagrams. Many monitoring programs use a combination of these forms and sometimes multiple forms in the same figure. To help provide definition to the task of developing a Network-wide monitoring strategy, the NCBN used the Conceptual Framework for the Development of Long-term Monitoring Protocols at Cape Cod National Seashore (CACO) (Roman and Barrett 1999; Appendix 1), as guidance in establishing a framework for the Network's Vital Signs program. CACO serves as the National Park Service prototype monitoring park for the Atlantic and Gulf Coast biogeographic region, and therefore face many of the same park management issues as the other Atlantic coastal parks in the NCBN.

Northeast Coastal and Barrier Network Conceptual Ecosystem Models

The NCBN has developed a monitoring framework that is ecosystem-based and issue-oriented similar to the CACO LTEM program. The ecosystem-based and issue-oriented approach recognizes the environmental processes and human activities that operate at various temporal and spatial scales, as well as acknowledging the natural and human-induced threats to ecosystems and responses to those threats (Roman & Barrett, 1999). Like the CACO LTEM program, the NCBN Vital Signs program has developed a number of conceptual models (stressor models) representing five main ecosystem types within its coastal parks. These models were developed to explain complex relationships among:

- *Agents of Change*, or the major external activities or processes that influence the natural system (natural processes or human activities);
- *Stressors* to each system, or the associated problems or products of human activities or natural events that alter the quality or integrity of the ecosystem (problems emerging from or related to the agents of change); and
- *Ecosystem Responses*, detectable changes that are in any measurable value of the ecosystem structure, function, or process (detectable changes in structure, function or process).

The first step in developing a framework for the NCBN, was to develop a single hierarchical model depicting the overall *agents of change*, *stressors* and *ecosystem responses* that pertain to all eight of the Network parks. Five hierarchical ecosystem models were then developed based upon this general model. In addition, one project-based visitor impacts model is presented here as well. This model is issue-based and can be applied to any of the five ecosystem types presented in the other models. These seven models demonstrate selected human or natural activities/processes that often are the source of stress on an ecosystem, in turn that can result in change to coastal park ecosystems. These models have and will serve as a foundation for selecting protocols and protocol attributes for the Network's monitoring program.

The first model presented is a general ecosystem model applicable to all NCBN parks. This general model was developed out of a compilation of information and discussion gathered during scoping workshops (both NPS and USGS), network working group meetings, network technical steering committee meetings and cooperator/I&M staff meetings. The other five models are ecosystem specific models for estuaries, salt marshes, freshwater, beaches, and uplands. These five models have and will provide guidance and structure to the development of monitoring protocols based within these five important and in some cases unique coastal park ecosystem types. The general model was used as a template for the development of the ecosystem specific models.

The NCBN General Ecosystem Model

Five broad categories of *agents of change* are presented in the Network's general model (Figure 4). These include:

- Natural Disturbance which includes both geomorphic and biotic processes. Examples are: sea level rise, predation, grazing, fires, and storms (hurricanes, floods, droughts).
- Land Use which includes any change in activity in land use patterns that influence natural systems. Examples are: watershed development, atmospheric inputs (pollution), population trends, and agriculture. Another important factor affecting coastal environmental quality in the Parks is watershed condition. Coastal watersheds or land areas that drain into the coastal zone, are nature's dynamic hydrologic systems that create and sustain aquatic ecosystems. Unfortunately, impaired watersheds also convey pollutants and sediments into park waters and undermine critical habitat of the coastal Parks. Many water quality issues and ecosystem problems are rooted in watershed conditions not just in the individual waterbody. Consequently, NPS needs to better understand watershed use, conditions, trends, and problems impacting on coastal watersheds where Parks are located in order to effectively respond to threats. NPS is developing a coordinated strategy for assessing coastal park watersheds and addressing these threats.
- Resource Consumption which includes groundwater extraction, fin and shell fishing, hunting, and sand mining.
- Visitor and Recreation Use which includes activities such as, trail formation, vegetation trampling, soil compaction, and wildlife disturbance
- Disasters such as chemical (e.g. oil) spills also play a role in shaping natural systems.

Six *stressors* resulting from the agents of change listed above are presented in the general model. These include, altered hydrology, altered landscape, invasive species, over harvesting, altered sediment inputs, and altered chemical inputs.

Ecosystem responses have been grouped into three major categories within the model. These include:

- Biotic Structure Changes which can be modifications to community composition, species interactions, biodiversity, and abundance,

- Ecosystem Function Changes or alterations in productivity, nutrient cycling, and energy flow; and

- Physical Environment Changes that can encompass changes in soil, water, and air chemistry.

Depending on the ecosystem type (e.g. estuaries, salt marshes, etc.) the agents of change can form a wide array of linkages to the stressors listed in the model. For example, change in land use patterns with the increase in watershed development and urbanization within the coastal zone can modify chemical, sediment, and hydrologic inputs within all coastal ecosystems, as woodlands are converted to commercial and housing developments. Ecosystem responses related to urbanization include altered community composition and abundance as wildlife habitat is destroyed, increased nutrient loading from septic and sewer systems, and changes in air chemistry occurs due to automobile emissions.

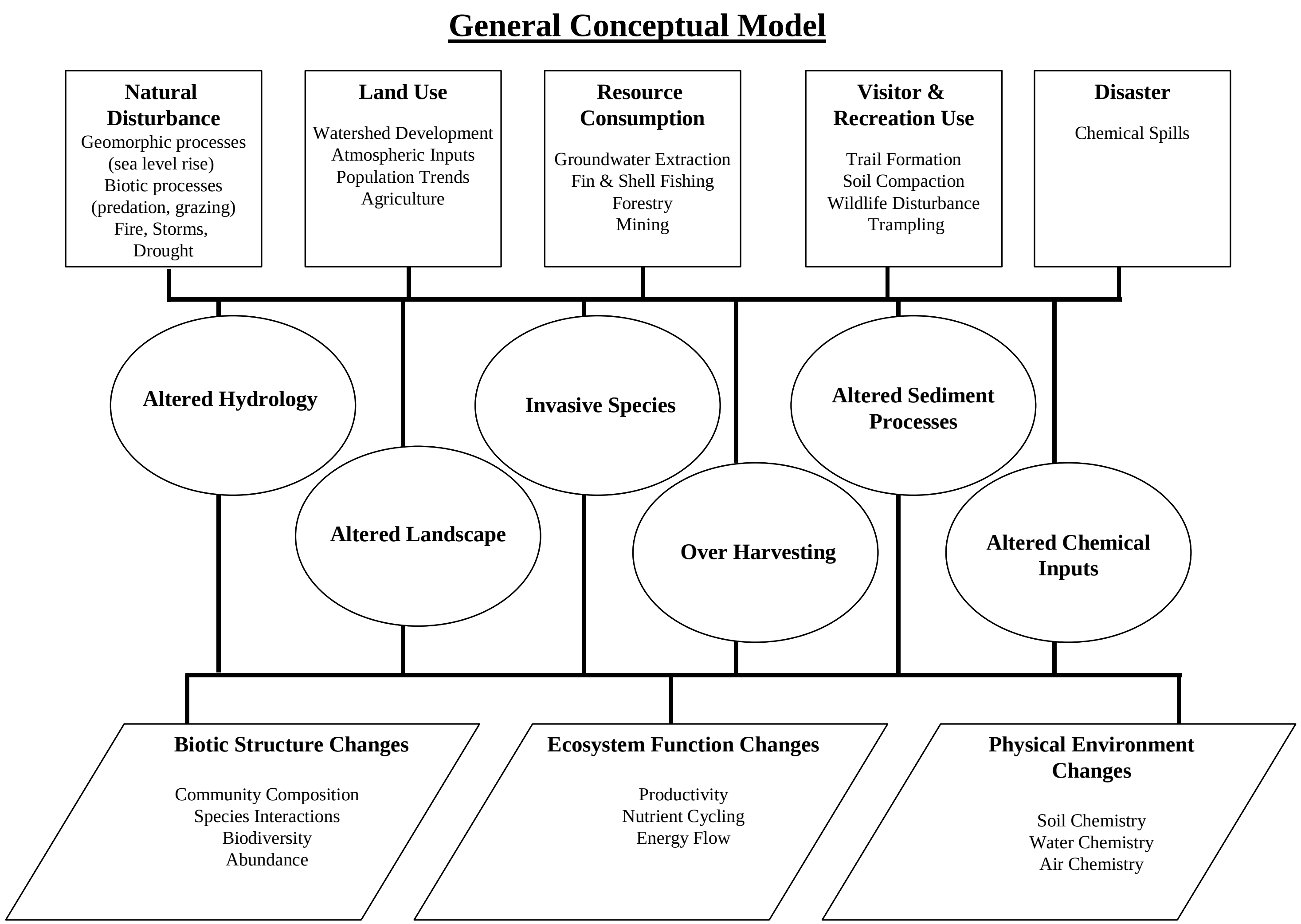

Figure 4. The Northeast Coastal and Barrier Network General Conceptual Ecosystem Model.

<u>The Five NCBN Ecosystem Models</u>

Salt Marsh Ecosystem Model

Salt marsh ecosystems provide habitat for a variety of species including recreational and commercial fishes, forage species, migratory shorebirds and waterbirds, as well as acting as erosion buffers and filters of nutrient inputs by intercepting and absorbing land derived runoff (Figure 5). A large percentage of the nations salt marshes have been altered, degraded, and lost over the past century. Restoration and subsequent monitoring of salt marsh habitat has recently become a management tool to rectify past environmental change (refer to Roman *et al*. 2001 for more details).

An estimated fifty percent of the nation's coastal wetlands have been completely lost, mostly by filling and dredging activities (Dahl 1990, Tiner 1984). Salt marshes have a long history of alteration from extensive networks of ditching for mosquito control or salt hay farming purposes, from restriction of tidal exchange by roads, causeways, bridges, and dikes, (Daiber 1986, Roman *et al.* 2000). As the coastal corridor becomes urbanized watersheds become increasingly developed and salt marsh acreage declines and becomes fragmented. Urbanization leads to increases in septic and sewer systems, air pollution, and intensified recreational use of coastal areas.

The ecosystem structure of salt marshes dramatically changes in response to ditching activities (*e.g.*, Bourn and Cottam 1950, Niering and Warren 1980) and restriction of tidal flow (*e.g.*, Roman *et al.* 1984, 1995). With ditching, the marsh may become drier and less salt- or flood-tolerant species may dominate (*e.g., Iva frutescens* and high marsh species), while restriction of tidal flow often results in conversion of *Spartina*-dominated to *Phragmites australis*-dominated marshes and allows for the expansion of other invasive species leading to further changes in ecosystem structure and function. Conversely, re-establishment of hydrologic conditions that were altered by ditching or tidal restriction often initiates a change or recovery back to typical marsh vegetation (Burdick *et al.* 1997).

Increased loading of nutrients or toxics to salt marshes, from coastal development served by on-site septic systems, alters ecosystem function and water quality. With nutrient enrichment of the coastal zone it is expected that primary production will increase leading to habitat changes. Nixon and Oviatt (1973), sampling along a nutrient gradient in Narragansett Bay, found production was substantially greater in high nutrient areas of the Bay compared to the lesser-developed and low nutrient sites.

Global climate change phenomenon such as sea level rise also influences salt marsh ecosystems. The rise in sea level along the Atlantic coast is estimated to increase by 0.5m by 2100 (Intergovernmental Panel on Climate Change, 1995). Changes in vegetation, sedimentation and erosion rates, or the conversion of marsh to mudflats or open water may result (Titus 1991). Salt marshes in New England appear to be keeping pace with sea level rise, but at some locations recent studies have documented changes indicating that the marshes are getting wetter and tending toward submergence or drowning (Warren and Niering 1993, Roman *et al.* 1997). Inlet migration dramatically influences hydrologic and sedimentation characteristics of marsh-dominated estuaries (Aubrey and Speer 1985). In response to the inlet dynamics and sea level rise, historic changes in ecosystem structure have been documented (Roman *et al.* 1997).

Other factors related to climate change can also affect salt marsh ecosystems. For example, with increased air temperatures, evaporation will accelerate leading to an increase in marsh salinities and changes in soil chemistry, perhaps resulting in the expansion of extreme salt tolerant halophytes and unvegetated marsh pannes. At present, salt marshes in more southern latitudes (*e.g.*, southeast Atlantic), with warmer climates, generally have a greater occurrence of halophytes adapted to extremely high soil salinity conditions (Bertness 1999).

Salt Marsh Ecosystem Model

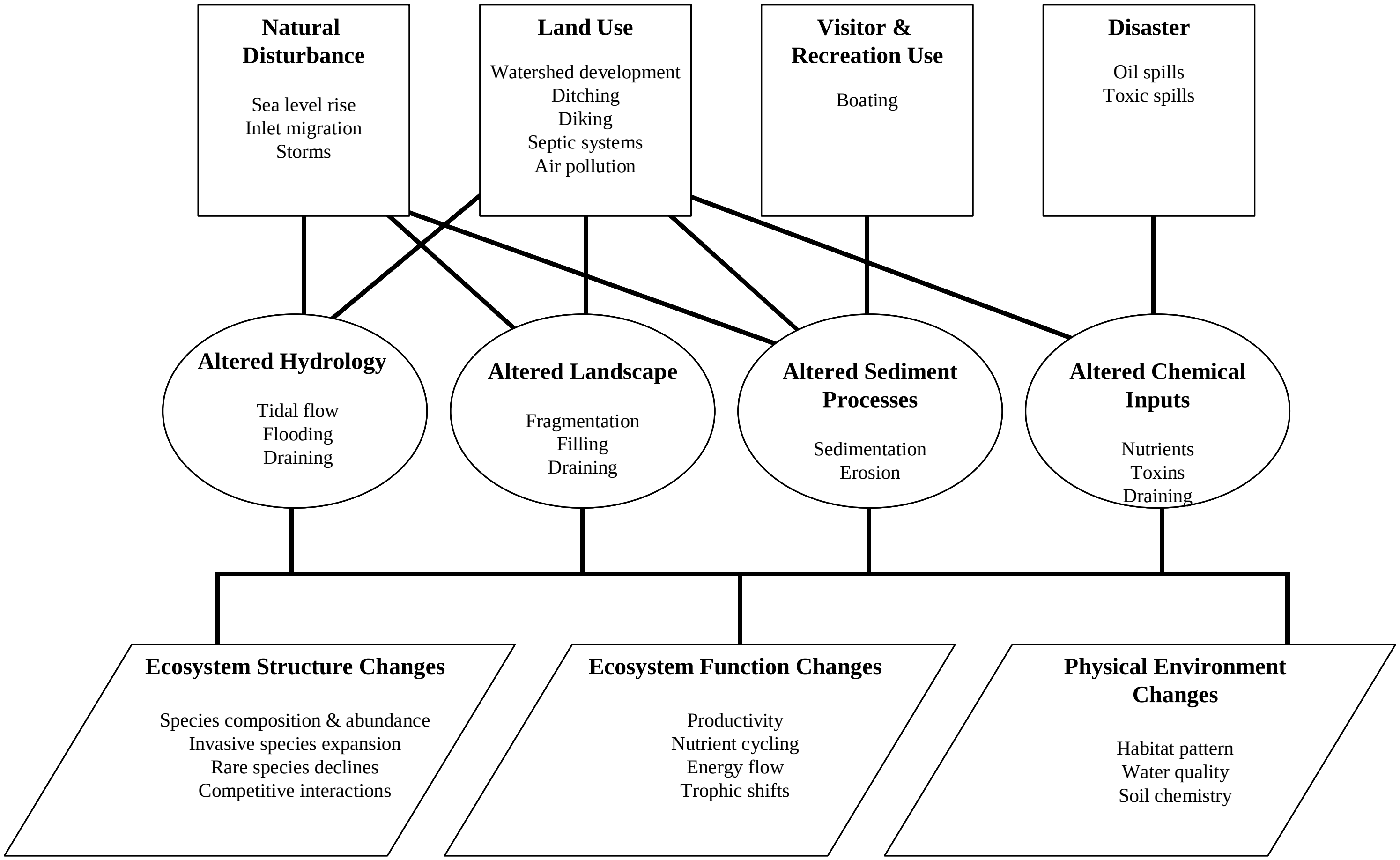

Figure 5. The Northeast Coastal and Barrier Network Salt Marsh Ecosystem Model.

Estuarine Ecosystem Model

Estuarine ecosystems are deep and shallow subtidal habitats and adjacent intertidal wetlands that are usually semi-enclosed by land but have open, partially obstructed, or sporadic access to the ocean and in which ocean water is at least occasionally diluted by freshwater runoff from the land (Mitsch and Gosselink, 1986). Many different habitat types are found in and around estuaries, including shallow open waters, freshwater and salt marshes, sandy beaches, mud and sand flats, rocky shores, oyster reefs, mangrove forests, river deltas, tidal pools, seagrass and kelp beds, and wooded swamps.
Estuaries are critical for the survival of many species. Many marine organisms, most commercially valuable fish species included, depend on estuaries at some point during their development. Tens of thousands of birds, mammals, fish, and other wildlife depend on estuarine habitats as places to live, feed, and reproduce. Estuaries provide ideal spots for migratory birds to rest and refuel during their journeys. And many species of fish and shellfish rely on the sheltered waters of estuaries as protected places to spawn, giving them the nickname "nurseries of the sea." (NERRS, 2003).
Besides serving as important habitat for wildlife, the wetlands that fringe many estuaries also perform other valuable services. As the water flows through fresh and salt marshes, much of the sediments and pollutants from the uplands are filtered out which benefits both people and marine life. Wetland plants and soils also act as a natural buffer between the land and ocean, absorbing flood waters and dissipating storm surges. This protects upland organisms as well as valuable real estate from storm and flood damage. Salt marsh grasses and other estuarine plants also help prevent erosion and stabilize the shoreline (NERRS, 2003) .
As the human population grows and the demands imposed on our natural resources increase, so too does the importance of protecting these resources for their natural and aesthetic values. Over many years, channels have been dredged within estuaries, marshes and tidal flats filled, waters polluted, and shorelines reconstructed to accommodate human housing, transportation, and agriculture needs. National Park Service units along the North Atlantic coast protect a total of about 1,891 square kilometers between Virginia and Maine. Approximately one quarter of this land area is submerged, including many coastal bays, estuaries, and lagoons (NPS 2000a).

NCBN Estuarine Ecosystem Model

Agents of Change

Human-caused agents of change are categorized within this model as Land Use, Resource Consumption, Visitor Recreation and Use and Disasters and examples of each type of these agents of change are identified. Storms, disease, geomorphic and biotic processes are listed as examples of Natural Disturbances.

Natural Disturbance
Natural disturbances can drastically alter an ecosystem. Shoreline geomorphic processes (e.g. beach and barrier migration, longshore sediment transport) can alter depth profiles,

change inlet morphometries, and bury estuarine biota. Natural coastal erosion is exacerbated by storms and hurricanes. For example severe weather events can create or block inlets to an estuary. Hydrology and landscape are immediately altered which then affect biotic, physical and function changes within an estuarine ecosystem. Biotic processes such as grazing (e.g. by Canada geese) and disturbance of bottom sediments (e.g. by foraging activities of horseshoe crabs and cownose rays) can have local impacts on seagrass cover. Disease may have more widespread impacts on estuarine seagrasses. For example, in the 1930's, eelgrass (*Zostera marina* L.) populations declined throughout most of its range from an epidemic of wasting disease (infection by the marine slime mould *Labyrinthula zosterae*).

Land Use/Disasters

The Northeast (from Maine to Maryland) currently accounts for about one third of the coastal population of the entire United States (NOAA 1998). The population density of this narrow coastal fringe is more than double that of any other region of the country, and it continues to grow. Therefore, estuaries in the northeastern US are particularly threatened by human disturbances within the densely populated coastal zone (Roman et al. 2000). Direct disturbance ariseses from coastal construction, dredge and fill activities, and shoreline stabilization (e.g. with bulkheads, revetments, riprap, and other types of shoreline armor). Indirect effects of residential, agricultural, and urban watershed development include increased nutrient loads to estuarine environments from atmospheric inputs, point source discharges, and diffuse, nonpoint sources.

Resource Consumption

Estuarine ecosystems can also be dramatically affected by the loss or lack of certain resources. For example, much of the watershed area of NPS coastal ecosystems lies outside protective park boundaries and is subject to intense developmental pressures. More and more groundwater is required for residential and commercial use including agriculture. Excessive groundwater extraction can decrease freshwater input to estuarine ecosystems, thereby altering the flushing rates, retention times, and salinity regimes. Acute and chronic effects of certain commercial fishing practices have also been documented. For example, trawling, dredging, and raking for bay scallops and hard clams have been found to damage eelgrass beds on the mid-Atlantic coast, and dragging for blue mussels has been found to have severe and long lasting effects on eelgrass in New England. Fin- and shellfish aquaculture operations can shade estuarine substrate and introduce large amounts of organic matter and nitrogenous waste into estuarine waters.

Visitor and Recreation Use

As populations in the Northeast continue to grow, visitation to Northeast National Parks is also increasing. Increased visitation can alter landscape, sediment process and chemical inputs. In particular, visitors to the Coastal and Barrier Network parks commonly use boats and jet-skis as recreational vehicles. These vehicles can alter sediment processes by increasing turbidity in shallower aquatic areas such as estuaries. Fuel spills and the discharge of contaminated bilge water into estuarine waters from pleasure boats creates altered chemical inputs to the ecosystem. Direct damage to seagrass beds from boat propellers, anchors, and mooring chains are an increasing source of local disturbance with the potential for large-scale cumulative impacts.

Stressors

Stressors to the estuarine environment are categorized as altered hydrology, altered landscape, altered sediment processes and altered chemical inputs.

Altered Hydrology

Hydrology plays a vital role in maintaining a healthy estuarine ecosystem. Changes to tidal flow, amounts of freshwater input can affect salinity, water temperature, and depth of water within an estuary. Short-term increases in waves and currents arise from natural events (e.g. storms), and long term alterations in wave climate and current regime can result from both natural (e.g. barrier breaches, inlet closure) and human disturbance (e.g. shoreline stabilization).

Altered Landscape

Most agents of change can cause small-scale disturbances in estuarine environments that, on a larger scale, result in fragmentation of specific habitat types. For example, direct physical disturbance, biotic processes, and recreational boating activities can transform continuous seagrass beds into islands of vegetation surrounded by bare substrate. Estuarine depth contours can be altered by filling or scouring caused by various natural and anthropogenic disturbances.

Altered Sediment Processes

Turbidity within an estuary can be increased through recreational activities such as boating. Dredging channels also drastically increases turbidity within the ecosystem. Increased turbidity decreases the availability of light and in turn affects water quality. Increased land development for timber, agriculture, residential and commercial purposes can lead to erosion and excessive sedimentation. Sediments are often deposited downstream along coastal shorelines. Excessive sediments not only increase turbidity but they can also carry excessive nutrients and pesticides, causing water quality problems. Erosion is also frequently associated with natural disturbance events (e.g. storms and hurricanes).

Altered Chemical Inputs

The major land-derived sources of nutrient pollution are fertilizers and wastewater (Valiela et al. 1992, Nixon 1995). Nutrients from agricultural fields and domestic septic systems enter streams and groundwater through runoff and leaching, where they contribute to nonpoint sources of enrichment. Domestic wastewater is also delivered to estuaries as point-source sewage discharge. Increasing nutrient loads in streams and groundwater are consequently associated with high rates of urbanization and agricultural expansion (Valiela et al. 1992, Nixon 1995). Atmospheric deposition of nitrogen from fossil fuel combustion and fertilizer volatilization may also form a significant portion of the total nitrogen load to coastal waters (Nixon 1995), particularly in estuaries that are large relative to the size of their watersheds (NRC 2000). Acute disasters such as oil and chemical spills may also introduce toxins into estuarine environments.

Ecosystem Responses

Ecosystem Function Changes

Estuarine environments are among the most productive on earth, creating more organic matter each year than comparably-sized areas of forest, grassland, or agricultural land. A healthy, untended estuary produces from four to ten times the weight of organic matter produced by a cultivated corn field of the same size (NERRS, 2003).

Understanding how the individual components of an ecosystem function together is virtually impossible. However, scientists know healthy ecosystem function depends on a particular balance from all of its resources. When one or more of these resources are stressed beyond recovery, the ecosystem begins to fail. Stressors such as altered hydrology, landscape, sediment processes and chemical inputs can all contribute to changes in native plant and animal productivity, trophic dynamics and energy flow, and nutrient cycling. Changes to ecosystem function ultimately change biotic structure and the physical environment.

Biotic Structure Changes

The tidal, sheltered waters of estuaries support unique communities of plants and animals, specially adapted for life at the margin of the sea. The productivity and variety of estuarine habitats foster an abundance and diversity of wildlife. Shore birds, fish, crabs and lobsters, marine mammals, clams and other shellfish, marine worms, sea birds, and reptiles are just some of the animals that make their homes in and around estuaries. These animals are linked to one another and to an assortment of specialized plants and microscopic organisms through complex food webs and other interactions. In an altered ecosystem, native species biodiversity and abundance tends to decline while exotic and invasive species abundance tends to increase and expand. Changes in biotic structure also include shifts in abundance of various native species, such as competitive displacement of seagrasses by algae following nutrient enrichment. Cascading effects of such a shift in composition and abundance of primary producers may include changes in the species compsistion and abundance of invertebrates and declines in fish and wildlife habitat value.

Physical Environment Changes

Changes in the physical characteristics of estuarine environments have far-reaching effects. Potential changes in water quality associated with all identified stressors include increased concentrations of nutrients and suspended material, decreased oxygen availability in bottom waters, decreased transmission of light to submerged rooted vegetation, increased organic content of sediments, and altered biogeochemical cycling. Changes in the bottom topography and consequent depth contours also result from altered hydrology, altered landscapes, and altered sediment processes. These changes in the physical environment will both influence, and be influenced by, the structure of estuarine biotic communities and ultimate ecosystem function.

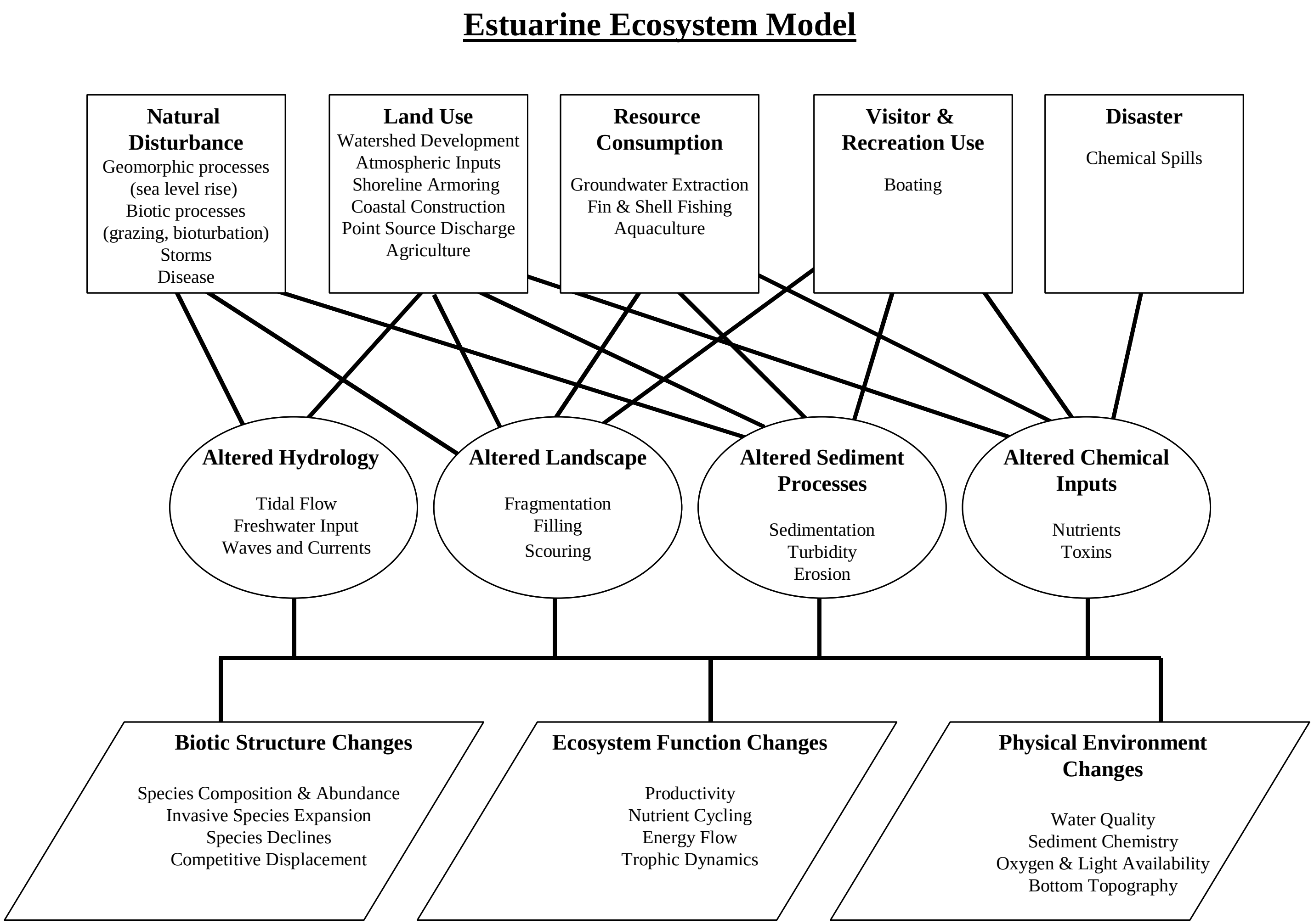

Figure 6. The Northeast Coastal and Barrier Network Estuarine Ecosystem Model.

Beach/spits/Dune Ecosystem Model

While there are several fundamental processes that drive the formation and evolution of Beach/Spit/Dune habitat, a controlling factor in their expression is the shallow geologic framework. Defined here as the geology of the near subsurface, the regional geologic framework exercises considerable influence over the response of nearshore and onshore environments to natural forces. While not a process in itself, knowledge of the geologic framework is critical to understanding short and long-term changes in coastal habitats. Operating on top of this framework are a number of natural and anthropogenic factors.

The primary natural processes influencing beach/spit/dune habitat include hydrographic conditions, sediment supply, and a suite of natural disturbance factors operating at local, regional, and global scales. Hydrographic conditions encompass a combination of physical and hydrologic features that include the nearshore system of bars, ridges, and shoals, and the continuous movement of water in the form of currents, waves, and tides. Collectively, these features and forces direct and control the movement of sediment through the nearshore system.

Ultimately, the presence of Beach/Spit/Dune habitat depends upon the availability of appropriately sized sediments within nearshore coastal environments. Finite in supply, especially along the mid-Atlantic coast, sediment availability serves as a limiting factor in the landform’s response to the forces of wind and waves. Sediment supply is susceptible to human disturbance and interruptions. When subject to prolonged changes in sediment supply, landforms may react in extreme ways with consequences to the physical environment and associated biota.

In the mid-Atlantic region of North America, natural disturbances consist mainly of atmospheric processes that provide both continuous and episodic energy inputs to the system. They create wind, waves and currents, the primary motive forces driving sediment transport in Beach/Spit/Dune habitat. While the processes are persistent, relative sea level change and storm events are the dominant factors.

Changes in relative sea level stem from a variety of global and local inputs including changes in ocean volume, tectonic seafloor shifts, and localized subsidence and rebound at the continental margins. Regardless of cause, sea level change results in the gradual shifting of the land/water interface (shoreline) in long-term patterns of retreat or advance. Storms on the other hand provide short-term energy pulses that can rapidly reshape Beach/Spit/Dune habitat. Whether expressed as tropical (e.g. hurricanes) or extra-tropical (e.g. nor’easters) systems, storm events move very large volumes of sediment (erosion and deposition) and can cause major habitat alterations through overwash-induced flooding and inlet formation. They may also cause substantial changes to nearshore subaqueous topography and thereby affect hydrographic processes.

Anthropogenic activities also have the potential to substantively alter the natural processes controlling Beach/Spit/Dune habitat, primarily though changes in land use within the coastal zone. Most significant are shoreline stabilization activities (e.g. groins; jetties; bulkheads), beach "nourishment" (to artificially increase local sediment supply), and dredging activities. Each of these practices has the potential to alter existing hydrographic conditions and sediment supply, and influence natural patterns of erosion/deposition, overwash, and inlet formation and migration. When this occurs, core processes are altered and naturally occurring stressors may begin to operate outside the range of natural variation. For example, a chronic sediment deficit caused by an "upstream" groin field or jetty system can result in dramatic changes in the volume and elevation of downdrift landforms. In turn, lower elevations facilitate overwash during storms and, as a consequence, may increase the potential for breaching and new inlet formation. Both are naturally occurring stressors acting on coastal barriers, but also subject to influence by human activities.

Each of the stressors identified in the conceptual model (Figure 7) cause change in Beach/Spit/Dune habitat, regardless of whether they operate as natural phenomena or as a product of human activities. The magnitude and scope of the resultant ecosystem response is complex and highly variable, and can often be cumulative. For example, local rates of natural shoreline erosion may be exacerbated by a human-induced reduction in sediment supply, creating a situation where part of the observed ecosystem response is of natural origin while part is anthropogenic.

In general, the most immediate ecosystem response to stressors is a direct change in the physical environment. At the extreme, this includes the loss and/or gain of habitats, such as when coastal erosion creates new aquatic habitat at the expense of terrestrial, or landscape-level reformation as may occur during strong storms. More subtle physical responses also include changes in geochemical and hydrologic conditions, such as alterations in groundwater quality and quantity.

Ecosystem response in the Beach/Spit/Dune Habitat can also be cascading. Stressor-induced changes in the physical environment often elicit secondary responses, such as changes in ecosystem structure or function. Structural responses, such as change in species composition or competitive interactions, generally reflect landscape-level alterations in the quantity and quality of specific habitat attributes. Similarly, functional responses such as changes in productivity or nutrient cycling may occur, often as a product of storm events and the associated reduction in habitat complexity.

Beach/Spits/Dune Ecosystem Model

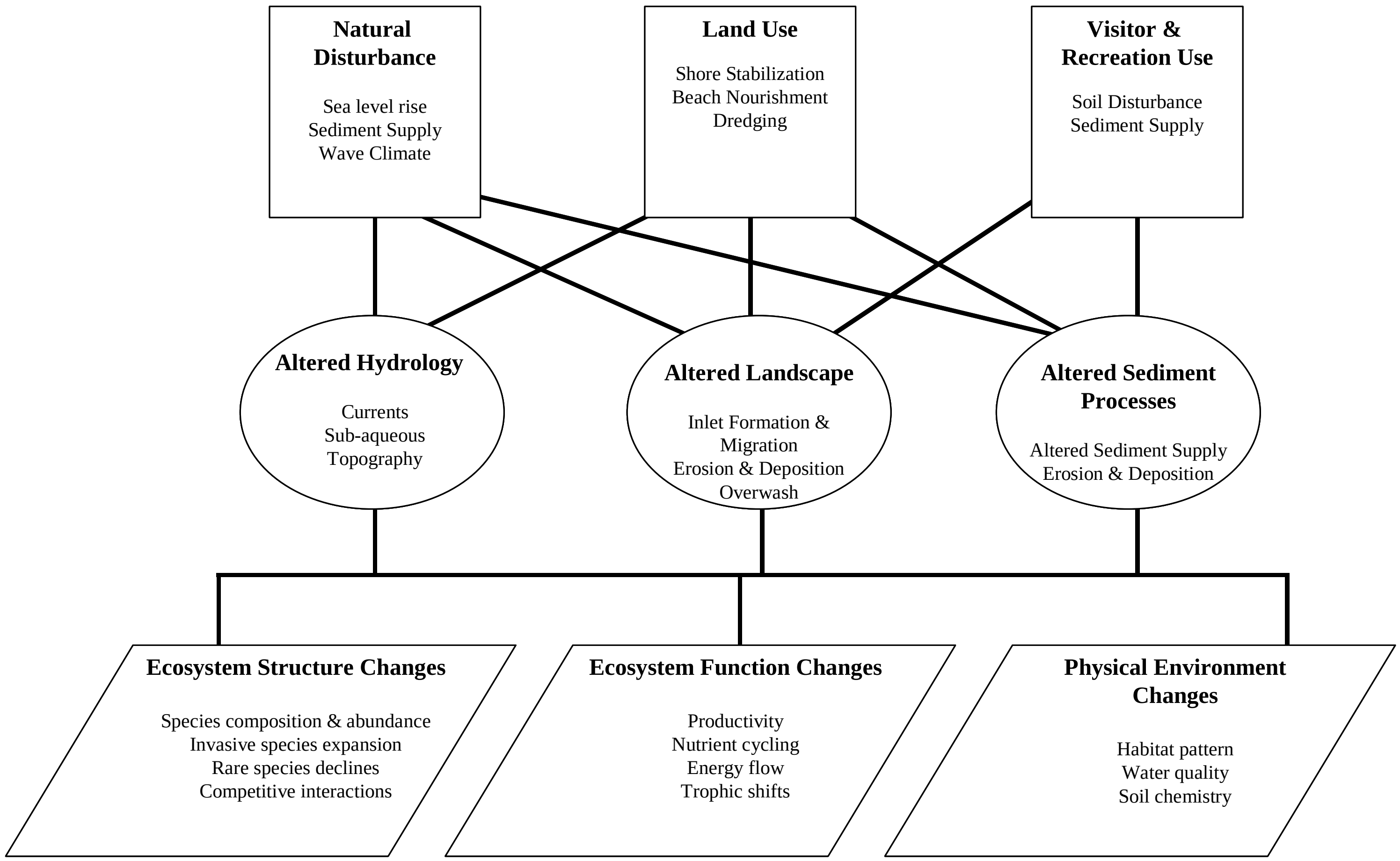

Figure 7. The Northeast Coastal and Barrier Network Beach/Spits/Dune Ecosystem Model.

Freshwater Ecosystem Model

(Note: The NCBN Freshwater Ecosystem Model and summary is currently under development. The following is a draft model (Figure 8). During the 2003 NCBN technical steering committee meeting, the committee agreed that inclusion of freshwater monitoring in the Network's vital signs program needs further discussion and review.)

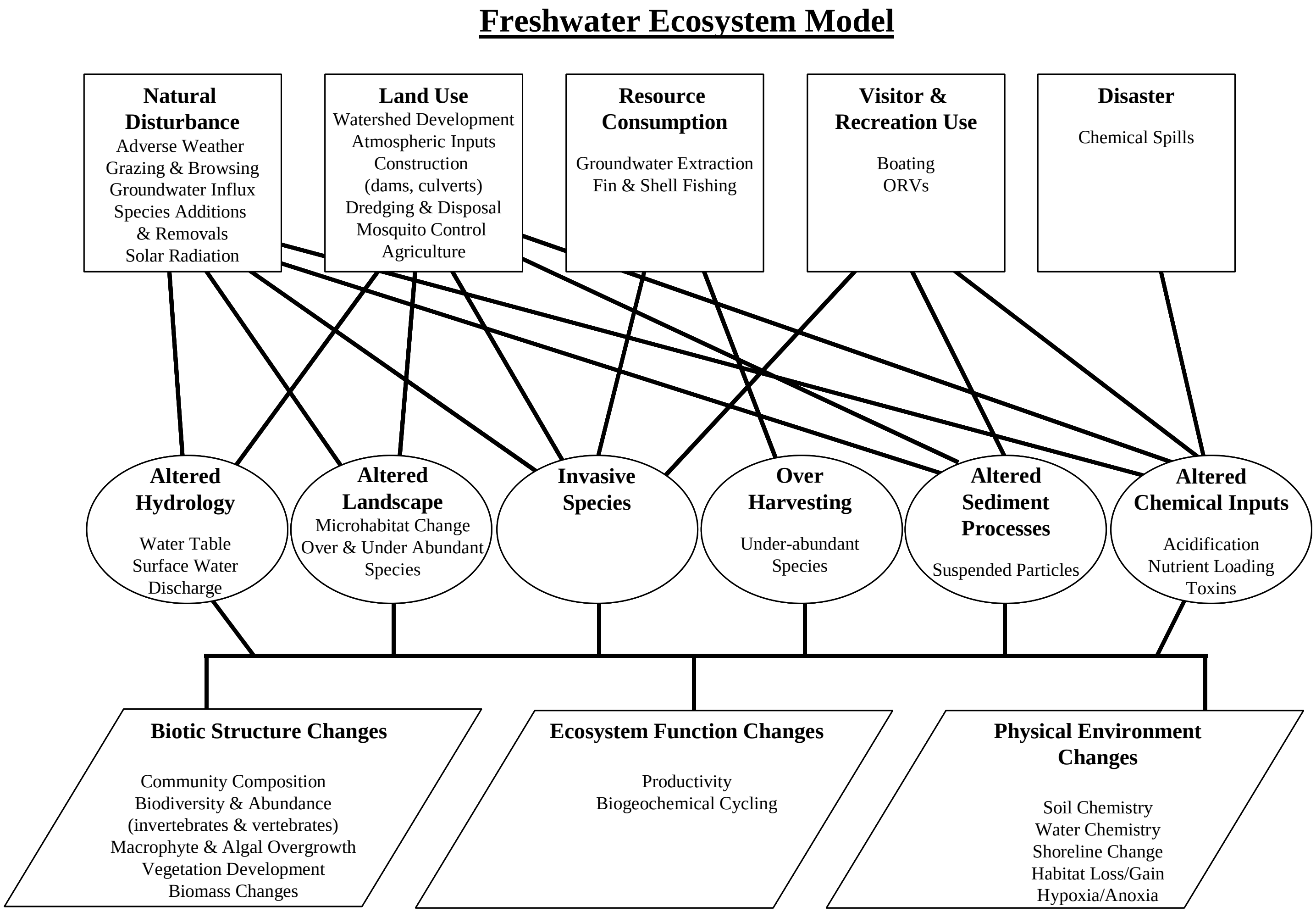

Figure 8. Draft Northeast Coastal and Barrier Network Freshwater Ecosystem Model.

Coastal Upland Ecosystem Model

(Note: The NCBN Upland Ecosystem Model and summary is currently under development. The following is a draft model; Figure 9)

Coastal uplands, typical of ecological communities in the coastal zone, are distinct in their characteristic zonation but generally less tolerant to the meterologic inputs (saltspray, wind, sand deposition) and dramatic climatic events (storms, hurricanes) than other communities of the coastal environment. The upland community includes the entire coastal floodplain and like other components of coastal ecosystems, are well adapted to the natural perturbations; however, when functioning under the human influences of urbanization, recreation, and pollution, the coastal upland environment is highly susceptible to change due to the complexities at the interface between the upland watershed and the associated hydrologic system. Coastal uplands are critically important for retention of runoff waters and in turn decrease estuarine flooding, local erosion, removal of pollutants ultimately serving as a filtration system. In the face of urbanization, coastal uplands also are important for the stability of the water table, that in turn affects the diffusion zone between fresh water reservoirs and the salt water environment.

Stress imposed on the coastal uplands is most evident by changes in plant development and associated biomass. This has important ramifications for uplands in this environment because of the relatively rapid development of organic matter in the soil (i.e., soil chemistry) and importance of nutrients delivered by meterologic inputs. Thus, biogeochemical cycling and forest development in coastal systems is a rapid process, an important consideration for recovery and management of protected areas along the coast.

Introduction of exotic and invasive species alter the landscape and the population dynamics of native fauna that can decrease amphibians and migratory birds of secure breeding sites. On the other hand, changes made to coastal uplands in recent decades by humans have increasingly diversified the landscape that promoting the increase of species like white-tailed deer. In either case, local animal populations, normally in synchronization with their surroundings, now demonstrate the paradox of either or under or overabundance. Conflicts with humans also affect the biodiversity of plant and animal populations. Elevated predator densities can decrease prey populations sometimes to levels below which populations can remain viable, an important consideration for small, rare or endangered populations. Prey populations also are important for the maintenance of trophic biodiversity and system productivity.

A variety of land use activities that include land development, fire suppression, and human recreation coupled with periodic severe weather events lead to changes in the upland environment that result in alterations throughout the entire coastal system.

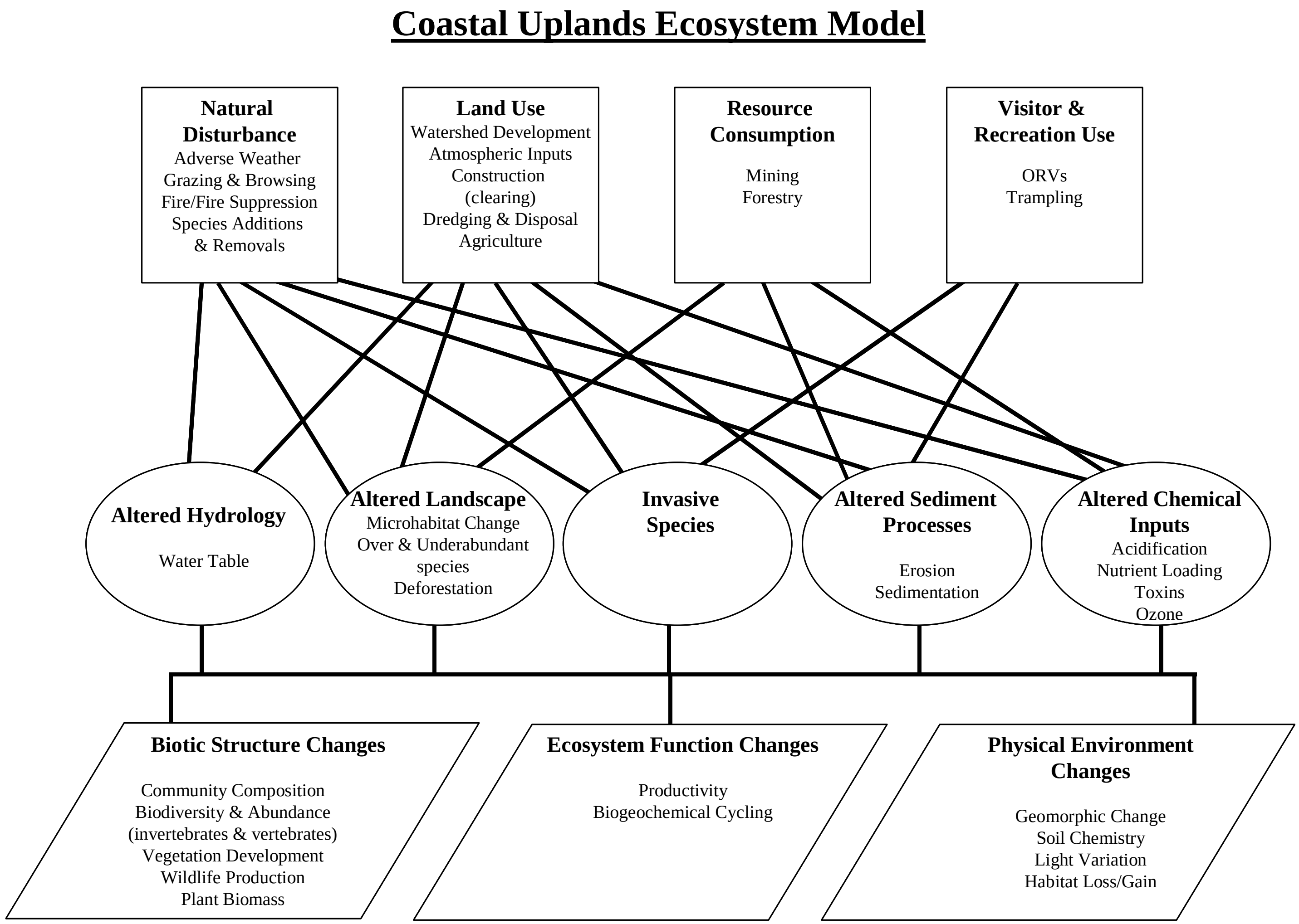

Figure 9. Draft Northeast Coastal and Barrier Network Upland Ecosystem Conceptual Model.

NCBN Issue-Based Model

Visitor Use Model

Visitors to coastal parks are engaged in a wide array of recreation activities, most of which generate some level of impact (refer to Monz et al. 2003). While visitor activity impacts may occur in many areas, impacts occurring within sensitive, natural/pristine, or protected zones are of most concern because of the ecological and social value of these areas.

Visitor impacts to coastal resources are a significant concern, although the degree of concern and the potential for significant impact is highly area dependent. For example, Gateway National Recreation Area, located in the New York City metropolitan area, sees over 8 million visits per year, with many visitors engaged in traditional beach activities such as swimming, sunbathing, and sport fishing. In many cases, the popular sites for many of these activities are in proximity of areas managed for high resource protection. Conversely, at Sagamore Hill National Historic Site the majority of visits occur in the museum facilities, with very little current activity on the trails and the small barrier island area.

Visitor activity can cause trampling to dune and upland vegetation communities as a consequence of day and overnight use. Trampling is primarily caused by foot traffic, in areas where visitors are dispersing and traveling off established trails and boardwalks. Mountain biking, legal and illegal off road vehicle (ORV) uses are sources of vegetation and soil disturbance and throughout the parks. The nature and extent of ORV use has changed substantially over the last 10-20 years with increases in numbers of visitors and shifts in visitor activity preferences. In the past, ORV use was largely limited to visitors engaged in sport fishing activities. As such, visitors would drive to an area above the tide line and park. Recently with the popularity of sport utility vehicles, more visitors are coming just to drive the beach, picnic, have campfires, swim, or to day hike into the nearby dune and forest communities. In some cases these impacts are localized, in point areas that attract visitors (i.e., campsites, coastal access points for fishing) and off hardened or resistant substrates (i.e., boardwalks and sand, respectively). In other cases these concerns are more widespread, such as the impacts of beach visitors to coastal sea beach amaranth, or the proliferation of trails from beach areas on to the dune ecosystems. Visitor activity can impact flora and fauna. For example, piping plovers (Charandrius melodus) and other seabird species occupy sand beaches and tidal flats and their numbers have been declining in recent years due to extensive beach disturbance. The vast majority of visitors are primarily interested in beach recreation and consequently there exists an ever present possibility of impacts to these species. Although significant management efforts are generally in place to limit visitor disturbance and preserve habitat during nesting season, it is not clear in all cases as to the level of visitor compliance with exclosures or the degree to which visitors in adjacent areas are causing a wildlife disturbance response. Contact with wildlife, such as the wild ponies of Assateague, may lead to undesirable behavioral modification. Impacts to vegetation include trampling and stem breakage, and the collection of plants or plant parts can cause damage to plant structures and may result in displacement of plant species or changes in plant populations. Resource consumption, such as the harvesting of fish, crabs, clams, and horseshoe crabs, and interactions with wildlife are concerns at several parks, especially where the extent and impact of illegal poaching is unknown. Resource consumption such as fin fishing can also lead to the introduction of non-native species (e.g. bait fish) which may further impact indigenous populations. Facility and access development, which are necessary to accommodate visitors, alter the immediate environment through the additional of roads, street lights, and visitor services. The presence of trash on the beaches, marshes, and other areas is a ubiquitous and constant management concern. In addition to the obvious impact to the visitor experience, concerns have been raised as to the effects of trash on wildlife.

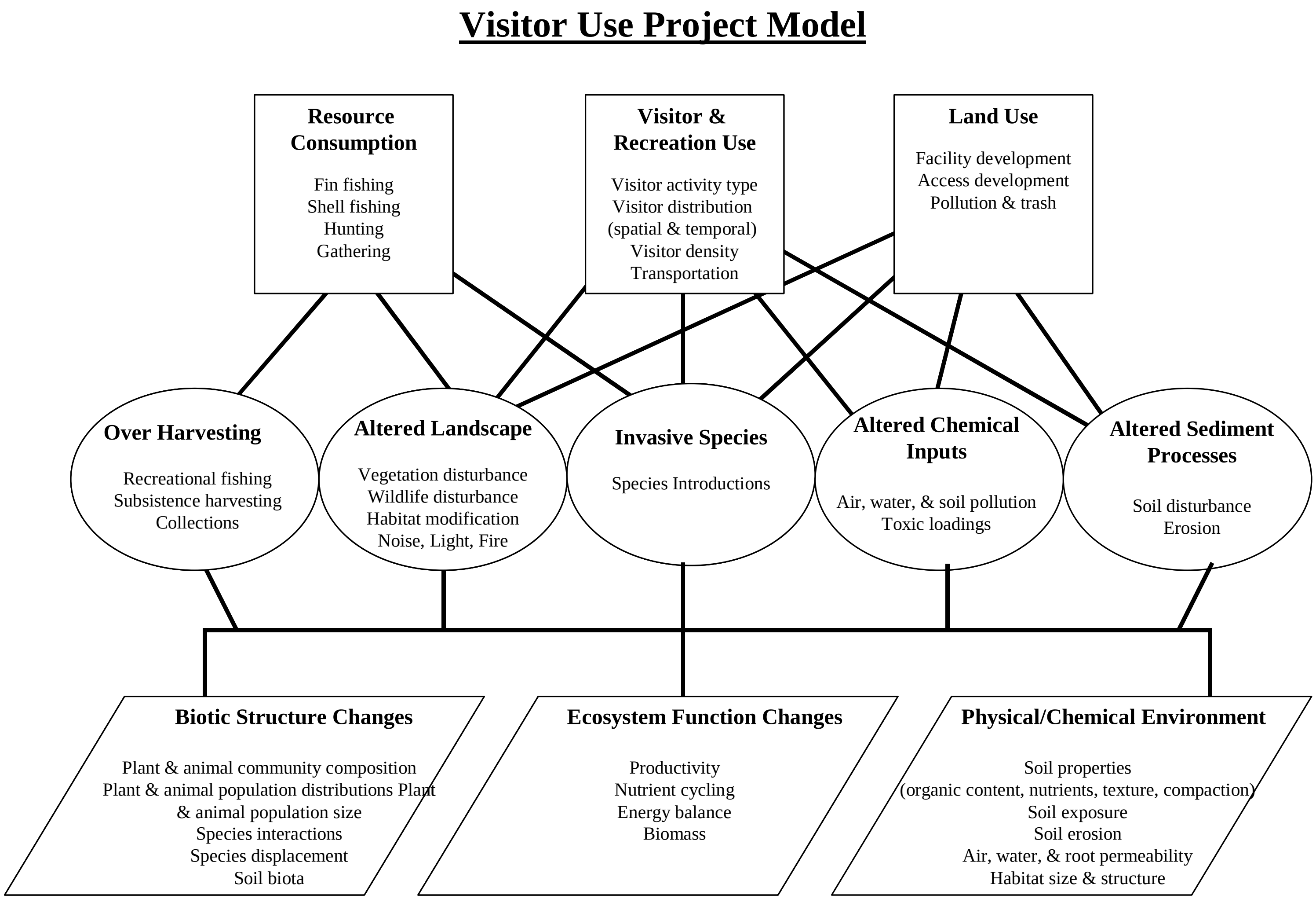

Figure 10. The Northeast Coastal and Barrier Network Visitor Impact Project Model. This is an issue-based model that can be applied to any of the NCBN ecosystem type models, Salt Marsh, Estuarine, Freshwater, Upland and Beach/Spit/Dune.

CHAPTER 3 VITAL SIGNS

INTRODUCTION

The National Park Service recognizes that it will not be possible to monitor all Natural Resources simultaneously. As a result, a Vital Signs monitoring program is being implemented. Vital Signs are measurable characteristics used to efficiently monitor changes in Agents of Change, Stressors, or Ecosystem Responses (see Chapter 2). Similar to its use in human health, a vital sign is a simple indicator of the overall status and health of natural systems. Vital signs are directly related to the conceptual models presented in Chapter 2. Given the high degree of similarity in ecosystem types, processes, and threats among NCBN Parks, the Network has chosen to develop a regional approach to Vital Signs Monitoring. The intent is to choose candidate vital signs and protocols that will be relevant to the collective needs of all parks. Once monitoring begins the network will be able to assess changing conditions within specific parks and to place these changes in a regional context by comparing trends and values with other parks. This regional approach will be strengthened by seeking ways to collaborate with other Federal, State, and Local agencies developing similar programs.

IDENTIFYING CANDIDATE VITAL SIGNS

Early in the process of designing a Vital Signs monitoring program the Technical Steering Committee agreed that the program should be structured on, not only the goals and objectives of the Servicewide Program (see Chapter 1), but those established as part of Cape Cod National Seashore's monitoring program, a prototype park. The Committee also decided that the general aim and goals of the Cape Cod monitoring program could help provide initial structure and basis for the development of the coastal network monitoring program because the issues faced by Cape Cod are also faced by the other seven Network parks. Through a series of meetings the technical steering committee identified the issues (see Chapter 1) and organized a vital signs scoping workshop for the Network.

The NCBN Scoping Workshop

On April 13 and 14, 2000, the first NCBN Vital Signs Scoping Workshop was held at Gateway National Recreation Area. Local scientists from other agencies and universities with expertise in coastal issues as well as members of the National Inventory and Monitoring program, and park and network staff were invited to attend. The goal of the workshop was to discuss the key management issues identified by the Technical Steering Committee and to develop a list of candidate "vital signs" or environmental indicators for each issue that could be further tested for possible inclusion in a long-term monitoring program for the Network. The forty-one people who attended were divided into five breakout workgroups based on the management issues, i.e., shoreline change, water quality, species and habitats of concern, resource extraction and recreation and visitor use. Each workgroup was assigned a leader, who guided the participants through discussion, development of monitoring questions, and selection and documentation of candidate vital signs. Workshop, workgroup reports were completed after the meeting and are included in the final workshop report (Appendix 14).

NCBN Issue-based Working Groups

In September 2000, the Coastal and Barrier Network Steering Committee met to review the scoping workshop report and plan the next steps for developing the Network's vital signs monitoring program (Appendix 13). The Committee decided that the scoping workshop was successful in developing "laundry lists" of vital signs for the Network, but agreed that smaller working groups were needed (no more than five people per group) to begin fine tuning the monitoring questions and lists of indicators developed by the scoping workshop workgroups. After review of the workshop report, the Committee recommended the formation of seven issues-based workgroups.

1. Shoreline Change
2. Estuarine Nutrient enrichment
3. Freshwater Quality
4. Water Quality (Contaminants only)
5. Visitor Use and Recreation
6. Animal and Plant Species and Habitats of Special Concern
7. Data management

Approximately five people were assigned to each workgroup under the direction of at least one Steering Committee member. The work groups were directed to review of existing Cape Cod protocols and Gateway workgroup reports, define and prioritize monitoring questions, identify candidate vital signs, evaluate existing monitoring programs, develop scopes of work to fill data gaps, and identify potential cooperators. Each group was asked to produce a written report by February 15, 2001; this process is shown graphically in Figure 11.

Four workgroups submitted reports to the Network (shoreline change (Appendix 22), estuarine nutrient enrichment (Appendix 8), freshwater quality (Appendix 7) and data management (Appendix 23). Of these, only two (estuarine nutrients and shoreline change) wrote scopes of work to receive Network funding. To address gaps in the areas of species and habitats of concern, freshwater quality, recreation use and visitor impacts, and contaminants, the Steering Committee and Network staff identified qualified collaborators and worked with them to develop additional projects.

NCBN Vital Signs Projects

In fiscal year 2001 the following projects were funded by the Network. The project title, investigators, and a brief abstract are listed below. Cooperators were asked to identify existing monitoring programs in existence in or near network parks (both NPS programs and those conducted by other federal, state, local and non-governmental organizations) and to assess which of these were potentially useful to the Network. Where appropriate, the projects were also required to develop conceptual models and a list of candidate vital signs.

Estuarine Nutrient enrichment and Freshwater Quality Projects

- Candidate Variables for Monitoring Estuarine Nutrient Enrichment within the NPS Coastal and Barrier Network, PI's: Blaine S. Kopp, USGS Patuxent Wildlife Research Center, Hilary A. Neckles, USGS Patuxent Wildlife Research Center, Charles T. Roman, NPS and Scott W. Nixon, University of Rhode Island Graduate School of Oceanography. This project includes a review of existing monitoring programs and activities relevant to the development of vital signs for estuarine water quality within the Coastal and Barrier Network parks. Candidate monitoring variables were identified for regional testing based on the conceptual model developed for the Cape Cod prototype monitoring program. This project was completed in FY2002 and a detailed report produced (Appendix 10). Additional funding was added in FY2002 to continue to refine the work and prioritize vital signs; a preliminary report is currently available (Appendix 24).

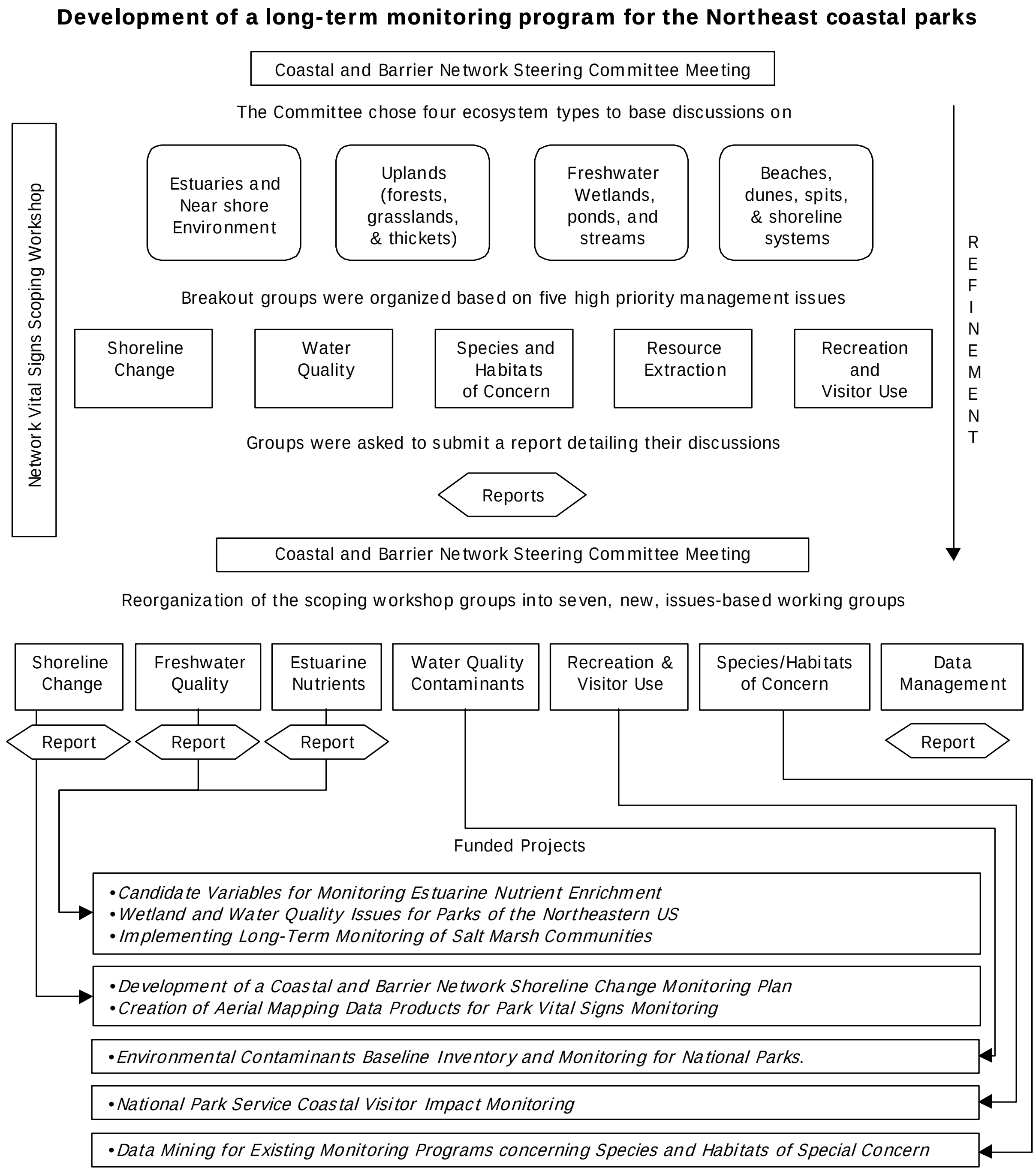

Figure 11. NCBN process for the identification, selection and prioritization of Network Vital Signs.

- Wetland and Water Quality Issues for Parks of the Northeastern US: A Scoping Report for the Coastal and Barrier Network. PI's: Mary-Jane James-Pirri, Graduate School of Oceanography, University of Rhode Island, Charles T. Roman, National Park Service. This is a two-year project to summarize threats and their potential effects on the structure and function of wetlands. In addition, existing monitoring programs will be evaluated and improvements suggested if appropriate.

Information from state 305(b) and 303(d) reports are to be summarized and discussed in light of the Network's need to identify pristine waters and impaired waters in the network. A preliminary report has been presented to the Network (Appendix 9) and a final report will be available by December, 2003.

- Implementing Long-Term Monitoring of Salt Marsh Communities within the Northeast Coastal and Barrier Network of the National Park Service, PI's: Mary-Jane James-Pirri, Graduate School of Oceanography, University of Rhode Island, Charles T. Roman, National Park Service. The Steering Committee recommended that the Network adopt the peer reviewed protocols developed for the Cape Cod prototype to monitor changes in Salt Marsh Vegetation (Roman *et al*. 2001; Appendix 17) and Nekton (Raposa and Roman 2001; Appendix 16). In FY2002 the Network funded a project to adapt these protocols for Network use and produce the protocols to be included in the Network's final monitoring plan. The published protocols have already undergone the process of data mining, conceptual model development, and identification of vital signs.

Recreation and Visitor Impacts Projects

- National Park Service Coastal Visitor Impact Monitoring, PI's: Christopher Monz, Ph.D., Sterling College and Yu-Fai Leung, Ph.D., North Carolina State University. The first phase of this project involved a data mining effort to compile existing information on visitor issues and concerns based on a scientific literature review, interviews with park managers and site visits. From this work a list of potential vital signs were identified. Phase one for the project was completed in FY2003 and a report was produced (Appendix 21). A second phase was funded in FY2003 to develop conceptual models and prioritize vital signs. A preliminary report is available (Appendix 25) with the final report due in October 2003.

Water Quality (Contaminants) Projects

- Environmental Contaminants Baseline Inventory for National Parks. PI's: Mark Robson, Rutgers University, and Keith Cooper, Ph.D., Cook College, Rutgers University. The first phase of this project will include a review of existing contaminant data from all sources (State, EPA, NPS, Corps of Engineers, etc) synthesized into a report for each of the Network parks. Compounds will be ranked based on a risk assessment that will be conducted. This project is an inventory of current conditions; once complete it may serve as the basis for additional monitoring. A final report is expected in fiscal year 2004.

Shoreline Change Projects

- Development of a Coastal and Barrier Network Shoreline Change Monitoring Plan. PI: Mark Duffy, ASIS GIS coordinator. Mark was detailed to the Coastal and Barrier Network to oversee the development of the shoreline change monitoring plan for the Network. This includes data mining, data development, needs assessment and protocol development. Mark has since joined the network as a permanent staff member. Detailed background information, a conceptual model, and a prioritized list of vital signs have been produced (Appendix 18).

- Creation of Aerial Mapping Data Products for Park Vital Signs Monitoring within Northeast Region Coastal and Barrier Network. PI's: John C. Brock and Laura J. Moore, USGS Center for Coastal Studies and Mark Duffy, National Park Service. This project will gather all existing NASA aerial mapping surveys of Coastal and Barrier Network parks, process the data using LaserMap software to produce survey-specific suites of GIS-compatible information products tailored to support vital signs monitoring. All previously collected LIDAR data sets for ASIS, GATE, CAPE COD and FIIS will be processed to create a separate set of information products for each of the park data sets. This project will serve as the basis for developing a LIDAR (LIght Detection And Ranging) based protocol for monitoring shoreline change (Appendix 18).

Species and Habitats of Concern Projects

- Data Mining for Existing Monitoring Programs within the Network concerning Species and Habitats of Special Concern. PI: Linda Arnold-Fabre,University of Rhode Island. Existing information on rare threatened and endangered species and habitats and keystone species in (or near) Network parks has been compiled and data obtained. This project reports on Vertebrate monitoring programs within the in and around Network Parks. A report summarizing this information is available (Appendix 20).

Review of Progress by the Technical Steering Committee 2003

In May 2003 the Technical Steering Committee met at George Washington's Birthplace to review the progress of the Network's Vital Sign Monitoring program. It was agreed that the scoping process and funded projects have demonstrated applicability of the Cape Cod framework to the Network as whole. One change, however, was recommended. Cape Cod recognizes an Estuary and Near Shore Ecosystem. The Network will now recognize Estuaries and Salt Marshes as separate ecosystems. This change was important because the Committee recommended that a generalized conceptual model be produced followed by separate models for each ecosystem type (see Chapter 2). The committee considered eliminating the Freshwater Ecosystem category due to its lower importance outside Cape Cod but decided to include for completeness. All agreed that focusing on Shoreline Change, Estuarine Nutrients, Salt Marsh Vegetation and Nekton, Visitor Impact Monitoring will lead to a robust vital signs monitoring program but that land cover change monitoring should be added to address gaps in the upland habitat and the species and habitats of concern issue. There is some concern that Thomas Stone N.H.S. will not be adequately represented in the Network monitoring program because it lacks marine habitats. Because Thomas Stone is more similar to parks in the National Capital Network than to other Coastal and Barrier Network parks the committee recommend the Network work the National Capital Network to see if their monitoring approach could be extended to include Thomas Stone. This issue will be included in the Network's work plan for 2004 (Appendix 26)

PRIORITIZATION OF VITAL SIGNS.

The prioritization process has varied greatly among projects. Three projects (Shoreline Change, Estuarine Nutrients, and Visitor and Recreation Impacts) have completed a full cycle of data mining, conceptual model development, and selection and prioritization of Vital Signs. A fourth project, Salt Marsh Monitoring, builds upon established protocols developed for the Cape Cod prototype. A fifth and final project, Land Cover Mapping, was proposed by the Technical Steering Committee in May 2003 to address gaps in the Upland areas and the species and habitats of concern issue. Below is a description of the process followed for each project.

Salt Marsh Monitoring

Salt marshes are important habitats in Coastal and Barrier Network Parks. The scoping process has identified salt marsh habitat loss as a major issue. Salt marsh monitoring is also important for monitoring long-term changes in the overall biological health of the parks because they integrate problems and processes associated with estuary and upland ecosystems as well. They're importance is also recognized by the Cape Cod prototype (Appendix 27). As a result monitoring protocols have already been developed by Roman *et al.* (2001; Appendix 17) and Raposa and Roman (2001; Appendix 16) to monitor salt marsh vegetation and nekton. These protocols have been implemented at Cape Cod and eleven Fish and Wildlife Refuges along the Northeast Coast. The protocols provide conceptual models and list specific vital signs for monitoring purposes (Table 8). The protocols are directly applicable to other Network parks so the Technical Steering Committee recommended that they be adapted for Network use. A pilot study was conducted at Fire Island N.S., Gateway N.R.A., and Colonial N.H.P. during the summer of 2003 to determine logistics of implementing these protocols in Network Parks. At the end of the summer the candidate Vital Signs were ranked based on sampling logistics. Below is a list the vital signs considered along with their rank (Table 8). Vital signs associated with the distribution and abundance of herbaceous vegetation and nekton were found to be logistically feasible and easily monitored and therefore were ranked high. Ancillary data on water table level and soil salinity required a sampling frequency beyond the means of the network and therefore ranked low.

Table 8. Vital signs for the salt marsh monitoring program. For each vital sign the recommended monitoring methods and priority rank (Low, Medium or High) are presented along with links to the ecosystem, management issues and the conceptual model.

					Ecosystem					Management Issues					
Program	**Category**	**Vital Sign**	**Monitoring Methods**	**Rank**	**Estuary**	**Salt Marsh**	**Beach**	**Uplands**	**Freshwater**	**Shoreline Change**	**Water Quality**	**Species & Habitats**	**Resource Extraction**	**Visitor Use**	**Link to Conceptual Model**
Salt Marsh Monitoring	Herbaceous Vegetation Distribution and	Species Composition	Fieldwork	High		X				X	X	X			Ecosystem response; community structure
		Percent Cover	Fieldwork	High		X				X	X	X			Ecosystem response; community structure
	Nekton (Fish and Decapods) Distribution and Abundance	Species Composition	Fieldwork	High	X	X				X	X	X			Ecosystem response; community structure
		Abundance	Fieldwork	High	X	X				X	X	X			Ecosystem response; community structure
		Size Structure	Fieldwork	High	X	X				X	X	X			Ecosystem response; community structure
	Water table level	Water table level	Fieldwork	Low	X	X				X	X	X	X		Alteration of Physical Environment
	Soil salinity	Soil salinity	Fieldwork	Low		X				X	X	X	X		Alteration of Physical Environment
	Relative sediment surface elevation	Marsh Surface Elevation	Fieldwork; SET's (Surface Elevation Tables)	High	X	X				X		X	X		Composite response to all stressors and agents of change; specific indicator of sea level rise

Although not currently part of the Salt Marsh protocols, the technical steering committee has recommended including marsh surface elevation as an additional vital sign and the shoreline change group has recommended it as well (see below) for monitoring change of estuarine shorelines. Marsh elevation is an excellent integrator of all the agents of change and stressors shown in the Salt Marsh Conceptual (Chapter 2) and has direct relevance to sea-level rise. Marsh elevation is currently being measured at Cape Cod N.S., Fire Island N.S., and Gateway N.R.A. with "Surface Elevation Tables" (SET's; see http://www.pwrc.usgs.gov/resshow/cahoon/). SET's are highly efficient method of determining elevation and are used worldwide. The Network is currently working with Don Cahoon (USGS), a leading expert in this technology, to explore the feasibility of adding SET's to additional sites in the Network.

Shoreline Change Monitoring

Monitoring shoreline change has been consistently chosen as a high priority monitoring issue for the coastal parks. Intense anthropogenic activities such as dredging and shoreline protection have disrupted geomorphologic processes resulting in dramatic alteration of natural patterns of sedimentation and accretion. Existing problems are further compounded by global climate change and sea level rise. As a result, parks are witnessing accelerating loss of natural, cultural, and recreational resources (Appendix 18).

The Network approach to developing a shoreline change program relies heavily on existing monitoring programs that are being developed for Assateague Island N.S., Gateway N.R.A., Fire Island N.S. and Cape Cod N.S. Most of these programs involve GPS mapping of the shoreline. Recently, collaborative arrangements with Wayne Wright of NASA and John Brock of the USGS have allowed the Network to utilize aircraft based LIDAR (LIght Detection And Ranging) to gain a more detailed understanding of topographic changes to islands and beaches for more information Appendix 18.

Information gained from existing programs coupled with scoping to determine park needs have been evaluated in a series of workshops. Workgroups composed of scientists, natural resource managers, and technical professionals from federal agencies, universities, and parks met at the following locations:

- USGS Patuxent Wildlife Research Center (February 1999; Appendix 12)
- Gateway National Recreation Area (April 2000; Appendix 14)
- USGS Woods Hole Field Center (January 2001; Appendix 22)
- University of Rhode Island Coastal Institute (October 2002; Appendix 18)

The goals of the meetings were to identify key scientific issues, information gaps, and long-term data relevant to coastal geomorphologic change and to identify a list of indicators or vital signs for monitoring shoreline change. The specific questions used to guide this process were:

- What is the rate of shoreline change for each park?
- What factors contribute to shoreline change? (Natural or anthropogenic?)

The group started with general feature descriptions and areas of concern and from there worked toward delineating specific measurable units. The Gateway and Woods Hole workshops focused their attention primarily on ocean shorelines and developed general feature categories for monitoring. The URI workshop, in addition to reviewing the results and recommendations of the previous meetings, also addressed the lower energy estuary issues and was much more exhaustive, detailed and specific regarding the identification of monitoring variables. The URI group went on to generate a lengthy list of potential variable indicators or vital signs and to prioritize them based on feasibility and information content (Appendix 18). Vital signs that gave good indications of the horizontal position of the shoreline and general beach and dune topography ranked high (Table 9). Other factors related to geology, hydrography, and bathymetry were considered necessary for a deeper understanding of the processes involved but were clearly beyond the scope of vital signs monitoring.

Table 9. Vital signs for the shoreline change monitoring program. For each vital sign the recommended monitoring methods and priority rank (Low, Medium or High) are presented along with links to the ecosystem, management issues and the conceptual model.

Program	Category	Vital Sign	Monitoring Methods	Rank	Ecosystem: Estuary	Ecosystem: Salt Marsh	Ecosystem: Beach	Ecosystem: Uplands	Ecosystem: Freshwater	Management Issues: Shoreline Change	Management Issues: Water Quality	Management Issues: Species & Habitats	Management Issues: Resource Extraction	Management Issues: Visitor Use	Link to Conceptual Model
Shoreline Change Monitoring	Shoreline Position	Shoreline Position	GPS Survey; Aerial Photography Lidar	High	X	X	X		X	X		X		X	Expression of altered landscape pattern and habitat loss or gain.
	Topography	Dune, Cliff & Bank Features	Aerial Photography: LIDAR	High			X			X		X		X	Expression of altered landscape pattern and habitat loss or gain.
		Edge of Vegetation	Aerial Photography; GPS Survey	High			X			X		X		X	Expression of altered landscape pattern and habitat loss or gain.
		Landscape Pattern	LIDAR; GPS Survey; 3D Survey	High	X	X	X		X	X	X	X		X	Expression of altered landscape pattern and habitat loss or gain.
		Location of Anthropogenic Structures/Disturbance	Aerial Photography; GPS Survey	High	X	X	X		X	X		X			Agent of change driving all stressors
		Marsh Surface Elevation	Fieldwork; SET's (Surface Elevation Tables)	Med.	X	X				X		X	X		Expression of altered landscape pattern and habitat loss or gain. Specific to estuarine shorelines
		Overwash fans/flood plain locations	GPS Survey; Aerial Photography Lidar	Med.	X	X	X	X	X	X	X	X			Indicator of areas of active change and potential threat to habitat
	Bathymetry	Depths	Acoustic Survey; LIDAR	Low	X					X					Linked to hydrography, sediment supply, and natural disturbance
		Location of Migrating Shoals & Bodies	Acoustic Survey; LIDAR	Low	X					X					Linked to hydrography, sediment supply, and natural disturbance
	Geology	Geologic Framework	Acoustic Survey; Seismic Survey; Cores	Low	X	X	X	X	X	X					Linked to overall geologic integrity/stability
		Sediment Size & Type	Sediment Samples	Low	X	X	X			X					Indicator of sediment supply
		Shore Type	Aerial Photography; GPS Survey	Low	X	X	X			X		X			Landscape pattern indicator
	Hydrography	Current Patterns	Regional Gauge	Low	X	X	X		X	X	X	X			Driver of erosion/deposition, overwash, inlet formation/migration
		Sea Level Position	Water Level Gauge	Low	X	X	X		X	X	X	X			Driver of erosion/deposition, overwash, inlet formation/migration
		Tide Range	Tide Guage	Low	X	X	X		X	X	X	X			Driver of erosion/deposition, overwash, inlet formation/migration
		Wave Characteristics	Local Gauge	Low			X			X		X			Driver of erosion/deposition, overwash, inlet

Estuarine Nutrients Monitoring

Approximately one quarter of the NPS land area within the Coastal and Barrier Network is submerged. These estuaries, bays, and lagoons serve as islands of relatively pristine aquatic habitat within the northeastern urban corridor. The North Atlantic coastal parks are dependent on high-quality aquatic resources to sustain the complex estuarine and near shore ecosystems they represent. Diverse threats to NPS estuaries exist, including natural disturbances (e.g. storms, sea-level rise), direct impacts of human activities (e.g. fishing, boating, dock construction), indirect effects of watershed development, and disasters (see Chapter 2). Of these, park managers throughout the network have repeatedly identified threats to coastal water quality as one of their highest priority management issues (Appendix

14). Much of the watershed area of NPS coastal ecosystems lies outside protective park boundaries and is subject to intense developmental pressures. Therefore, there is great potential for human disturbances to coastal watersheds to result in increased nutrient loading to park estuaries. Estuaries can generally assimilate some degree of enrichment without major ecological ramifications, but excessive nutrient inputs typically lead to dense blooms of phytoplankton and fast-growing macroalgae, loss of sea grasses, and decreased oxygen availability in sediments and bottom waters. Ultimately, cascading effects include changes in the species composition and abundance of invertebrates, decline in fish and wildlife habitat value, and the collapse of fin- and shellfish stocks. Protecting the ecological integrity of park estuaries depends on implementing a scientifically-based monitoring program that is capable of diagnosing local causes of nutrient enrichment, detecting changes in nutrient loads, and determining if nutrient inputs are near to exceeding thresholds that would result in shifts in ecosystem structure and function.

An estuarine nutrients workgroup was formed during the network scoping workshop and they began the work of developing a conceptual model and identifying candidate vital signs. Since many state, local, and federal agencies are already involved in monitoring water quality in the estuaries of the Northeast coast. The workgroup was also given the task of identifying existing sources of monitoring data. As a guide to the process, the following monitoring questions were identified as relevant:

- ❖ Are nutrient loads to park estuaries increasing?
- ❖ Are estuarine resources changing in response to nutrient inputs?
- ❖ What are the sources of nutrient enrichment?

Upon receipt of a detailed report (Appendix 10) the Network funded a project to prioritize the extensive list of vital signs. Individual potential variables were evaluated in terms of established characteristics of effective monitoring variables (Table 10). Some variables were eliminated because they were difficult or costly to measure (e.g. nutrient loading, denitrification rates, agricultural runoff), others because they exhibit high variability (e.g. macroalgal density, dissolved nutrient concentrations), and still others because the predictability of their relationship to nutrient enrichment is still being researched (e.g. index of biotic integrity, indicator species) or is unknown (fecal indicator bacteria). The most effective monitoring programs include variables that span levels of ecological organization (organisms to landscapes), relationships (causes of and responses to stress) and complexity (structure, function, and composition). Consequently, each variable was also evaluated in terms of its relative contribution to a collective suite, with the goal of including representatives of different scales, trophic levels, and relationships to nutrient enrichment. Finally, potential variables were evaluated for consistency with two NPS programs also under development (national water quality monitoring in marine/estuarine waters; water quality inventory protocols for estuarine/marine systems), and with the long-standing Environmental Monitoring and Assessment Program / National Coastal Assessment of the US Environmental Protection Agency. Thus, the final list of candidate indicators for this protocol was influenced by both scientific and practical considerations. The prioritized list of vital signs is presented below (Table 11). All vital signs associated with land use change were selected for inclusion. Because these data can be harvested from existing sources analyses can be made on past, current, and (later) future conditions. Vital signs associated with water quality are measure ecosystem responses to eutrophication and are excellent surrogates for the stressors (i.e, nutrient inputs) themselves. Perhaps the single greatest indicator of water quality health is the distribution and abundance of submerged aquatic vegetation (SAV). SAV integrates problems seen at all levels and is true biotic indicator of water quality. State SAV mapping programs exist for all parks except those in New York.

Table 10. Characteristics of effective monitoring variables (after Jackson *et al*. 2000, Dale and Beyeler 2001, Kurtz *et al*. 2001; see also Appendix 24).

Characteristics of Effective Monitoring Variables
Relevant to management concerns and ecological resources
Address monitoring questions of interest
Have known linkage to ecological function or critical resource of interest
Are at appropriate scale to answer specific monitoring questions
Are integrative in space and time, so that the full suite of variables provides assessment of entire system of interest
Applicable for use in a monitoring program
Are easy and practical to measure
Are non-destructive or low impact to measure without disturbing monitoring site
Are measurable using standard, well-documented methods
Generate data that are compatible with other systems
Are cost-effective to measure
Responsive to anthropogenic stresses
Have known sampling and measurement error
Have low natural variability
Have known variability in time and space
Are sensitive to anthropogenic stresses on the system or resource of interest, while having limited and documented sensitivity to other factors (i.e. to natural variation in ecosystem condition)
Interpretable and useful to environmental decision-making
Respond to stress in a predictable manner
Are anticipatory: signal impending change in ecosystem before substantial degradation occurs
Are linked to management decisions; predict changes that can be averted by management action, or document success of past actions
Have known or proposed thresholds of response that delineate acceptable from unacceptable ecological condition
Can be communicated to managers and the public

Table 11. Vital signs for the estuarine nutrients monitoring program. For each vital sign the recommended monitoring methods and priority rank (Low, Medium or High) are presented along with links to the ecosystem, management issues and the conceptual model.

					Ecosystem					Management Issues					
Program	Category	Vital Sign	Monitoring Methods	Rank	Estuary	Salt Marsh	Beach	Uplands	Freshwater	Shoreline Change	Water Quality	Species & Habitats	Resource Extraction	Visitor Use	Link to Conceptual Model
Estuarine Nutrient Monitoring	Land Use Change	Land use/land cover	Remote Sensing; GIS	High	X	X	X	X	X	X	X	X	X	X	Major Agent of Change
		Nutrient point-source discharge permits	Data Harvesting	High	X	X	X	X	X	X	X	X	X	X	Measure of the Land Use Agent of Change
		Atmospheric N deposition	Data Harvesting	High	X	X	X	X	X	X	X	X	X	X	Major Agent of Change
		Water use for agriculture & domestic consumption	Data Harvesting	High	X	X	X	X	X	X	X	X	X	X	Measure of the Land Use Agent of Change
		Fertilizer consumption	Data Harvesting	High	X	X	X	X	X	X	X	X	X	X	Measure of the Land Use Agent of Change
		Livestock populations	Data Harvesting	High	X	X	X	X	X	X	X	X	X	X	Measure of the Land Use Agent of Change
		Housing density	Data Harvesting	High	X	X	X	X	X	X	X	X	X	X	Measure of the Land Use Agent of Change
	Water Quality	Dissolved oxygen	Water Sampler	High	X						X				Measure of Physical Environment Change
		Chlorophyll a	Water Sampler	High	X						X				Measure of Ecosystem Structure and Function Changes
		PAR (photosynthetically active radiation) light attenuation	Water Sampler	High	X						X				Measure of Physical Environment Change
		Turbidity	Water Sampler	High	X						X				Measure of Physical Environment Change
		Temperature	Water Sampler	High	X						X				Measure of Physical Environment Change
		Salinity	Water Sampler	High	X						X				Measure of Physical Environment Change
	Submerged Aquatic Vegetation (SAV) Distribution & Abundance	SAV bed size, structure, and location	Remote Sensing; GIS; Fieldwork; Data Harvesting	High	X						X	X			Species declines associated with water quality degradation
		Within SAV-bed percent cover, shoot density, biomass	Fieldwork	Med.	X						X	X			Species declines associated with water quality degradation
		SAV tissue Nitrogen	Fieldwork; Laboratory Analysis	Med.	X						X	X			Species declines associated with water quality degradation

Visitor Impact Monitoring

Visitor impacts to coastal resources are a significant concern to resource managers in all Network Parks. The degree of concern and the potential for significant impact, however, is highly area dependent. For example, Gateway National Recreation Area, located in the New York City metropolitan area, sees over 8 million visits per year, with many visitors engaged in traditional beach activities such as swimming, sunbathing and sport fishing. In many cases, the popular sites for many of these activities are in proximity of areas managed for high resource protection. Conversely, at Sagamore Hill National Historic Site the majority of visits occur in the museum facilities, with very little current activity on the trails and the small barrier island area. Given these differences, the visitor impacts workgroup recommended that comprehensive scoping be completed for each park (Appendix 14).

To guide the process the following set of monitoring questions were developed:

- Which NCBN parks are in need of visitor monitoring and visitor impact monitoring programs?
- What are the management areas of critical concern where current or potential visitor activities threaten resource quality and compromise resource protection objectives?
- In areas of critical concern, how are the type, amount and distribution of visitor use changing over time?
- In areas of critical concern, what is the type and extent of visitor impacts to soil, vegetation and wildlife resources and how are these impacts changing over time?

This project was initiated in 2001 and a final report produced in 2003 (Appendix 21). Work continued through the summer of 2003 resulting in a set of habitat specific conceptual models and a prioritized list of vital signs (Appendix 25).

The selection of accurate and appropriate vital signs of resource conditions is essential to the development of any program of long-term monitoring. For the visitor impact monitoring project a three-step process was used to select and prioritize vital signs. First, conceptual models of the interactions of agents of change, stressors and ecosystem responses were developed for visitor impacts in coastal ecosystems and for the soil, vegetation and wildlife responses within those ecosystems (Appendix 25). This conceptual model approach is helpful to illustrate the mechanisms of impact and the ecosystem-level consequences of those impacts. Second, candidate vital signs were identified based on the conceptual models and the scoping results. Finally, candidate vital signs were evaluated against thirteen selection criteria derived from a literature review (Table 12). A matrix approach was used to assign each vital sign a numerical rank. The results are presented as a prioritized list of candidate vital signs (Table 12; Appendix 25).

Table 12. Evaluation criteria for visitor impact vital signs. The first four criteria are required while the remaining nine are desirable criteria. These criteria were adapted from Belnap (1998), Consulting and Audit Canada (1995), GYWVU (1999) and Manning *et al.* (*in prep*).

CRITERIA	DESCRIPTION
Low measurement impacts	The indicator can be measured with no or minimal level of ground disturbance
Reliable/Repeatable	The measurements of indicator by different field staff would show reasonable agreement
Correlation with use	The indicator is directly related to visitor use with good level of correlation
Ecologically relevant	The indicator must have conceptual relevance to concerns about ecological condition, i.e., it must be a component of the appropriate conceptual model. It must reflect an important change of resource condition that would lead to significant ecological or social consequences
Respond to impacts	Change of resource condition can occur promptly after impacts are introduced
Respond to management	Resource conditions can be manipulated by management actions
Easy to measure	Field measurements are relatively straightforward to perform with minimal level of equipment needed
Low natural variability	Indicator has a limited level of spatial and temporal variability
Large sampling window	Field measurements can take place in most of the times in a year
Cost effective	Measurements of indicator are inexpensive. Little additional cost to management. Data gathered benefit management
Easy to train for monitoring	Field staff with no prior knowledge of field procedures can be easily trained to perform such procedures
Baseline data	There are existing data on the indicator, preferably with the use-impact link established
Response over different conditions	Impacts can be seen while still relatively slight

For vital signs related to the measurement visitor use, the agent of change, monitoring of visitor distribution was ranked high and will provide much needed information to resource managers. For visitor affects on natural resources, habitat alteration, vital signs related to visitor use of “off trail” areas scored highest. The visitor impact group recommends monitoring social trail proliferation, the formation of unofficial sites, changes in soil exposure. Finally, they recommend monitoring visitor-wildlife interactions; specifically wildlife attraction (Table 13; Appendices 21 and 25).

Table 13. Vital signs for the visitor impact monitoring program. For each vital sign the recommended monitoring methods and priority rank (Low, Medium or High) are presented along with links to the ecosystem, management issues and the conceptual model.

Program	Category	Vital Sign	Monitoring Methods	Rank	Ecosystem					Management Issues					Link to Conceptual Model
					Estuary	Salt Marsh	Beach	Uplands	Freshwater	Shoreline Change	Water Quality	Species & Habitats	Resource Extraction	Visitor Use	
Visitor Impact Monitoring	Visitor Use	Distribution	Fieldwork	High	X	X	X	X	X	X	X	X	X	X	Major Agent of Change
		Visitor Density	Fieldwork	Med.	X	X	X	X	X	X	X	X	X	X	Major Agent of Change
		Visitor Activity Type	Fieldwork	Med.	X	X	X	X	X	X	X	X	X	X	Major Agent of Change
	Habitat Alteration	Vegetation Loss/ Soil Exposure	Remote Sensing; GIS; Fieldwork	High	X	X	X	X		X	X	X		X	Ecosystem responses to visitor use
		Vegetation Compositional Change	Remote Sensing; GIS; Fieldwork	Med.	X	X	X	X	X	X	X	X		X	Ecosystem responses to visitor use
		Social Trail Formation	Remote Sensing; GIS; Fieldwork	High			X	X		X		X		X	Habitat Alteration stressor
		Unofficial Site Formation	Remote Sensing; GIS; Fieldwork	High			X	X	X	X	X	X		X	Habitat Alteration stressor
		Shoreline Disturbance	Remote Sensing; GIS; Fieldwork	Low			X			X		X		X	Habitat Alteration stressor
		SAV Disturbance	Remote Sensing; GIS; Fieldwork	Low	X						X	X			Plant community response
	Wildlife Disturbance	Wildlife Disturbance type	Fieldwork	Med.			X	X				X		X	Wildlife Response to stressors
		Wildlife Disturbance time	Fieldwork	Med.			X	X				X		X	Wildlife Response to stressors
		Wildlife Attraction Behavior	Fieldwork	High	X	X	X	X	X			X		X	Wildlife Response to stressors

Land Cover Change Monitoring

The final vital sign, land cover change, was proposed by the Technical Steering Committee (TSC report 2003) to address a major gap in the monitoring program. Most efforts to date have concentrated on shoreline, estuaries, and salt marshes with little attention given to upland areas. Data mining recommended by the species and habitats of concern workgroup resulted in a comprehensive report on vertebrate monitoring programs in and around network parks (Appendix 20) but did not lead to any definitive issue-based monitoring questions. The technical steering committee discussed the Network’s needs for upland areas and recommended monitoring vegetation change. Vegetation maps are being developed for all Network parks and will be complete by 2005. The steering committee recommended the formation of a workgroup to examine the feasibility of using the vegetation maps as baseline for continued monitoring of vegetation change. The inclusion of land cover change as a vital sign is desirable because it will provide information on all five major ecosystems of the network and will be relevant to the Networks all of the Networks major issues (Table 14). As a first step, a new project was initiated with Dr. Y.Q. Wang (University of Rhode Island) to investigate whether Satellite data could be used to reproduce the newly complete vegetation map for Fire Island N.S. and to produce a protocol for change detection analysis. If successful, this will allow the network to develop a cost effective program of land cover change monitoring.

Table 14. Vital signs for the land cover change monitoring program. For each vital sign the recommended monitoring methods and priority rank (Low, Medium or High) are presented along with links to the ecosystem, management issues and the conceptual model.

Program	Category	Vital Sign	Monitoring Methods	Rank	Ecosystem					Management Issues					Link to Conceptual Model
					Estuary	Salt Marsh	Beach	Uplands	Freshwater	Shoreline Change	Water Quality	Species & Habitats	Resource Extraction	Visitor Use	
Land Cover Monitoring	Landcover Change	Changes in terrestrial vegetation assemblages (from baselines established by the vegetation mapping program)	Remote Sensing; GIS	High	X	X	X	X	X	X	X	X	X	X	ER, Biotic: Vegetation Development

RELATIONSHIP OF VITAL SIGNS TO NETWORK ECOSYSTEMS AND MANAGEMENT ISSUES

A total of 53 vital signs were proposed. Of these, 31 were ranked as high priority, nine as medium priority and 13 were ranked low (Table 15). In a few cases there are some redundant vital signs. For example, marsh elevation was ranked high for salt marsh monitoring and medium for shoreline change monitoring. This introduces some bias into the table but does not affect the overall conclusions. The highly ranked vital signs show the expected trend of greater emphasis on estuaries, salt marsh and beach/spit/dune ecosystems and their associated management issues of shoreline change, water quality, and species and habitats.

The high degree of similarity among Network parks and a clear understanding of resource threats have greatly facilitated the development of the Network's Vital Signs monitoring program. If the Network is able to implement protocols to monitor the high priority vital signs already identified, it will be in an excellent position to provide resource managers with the information they need to effectively detect and manage change. Through out the entire process, the Network has continuously returned to the need to monitor shoreline change, estuarine nutrients, salt marsh vegetation and nekton, visitor impacts, and land cover. This decision is supported by a review and prioritization process recently completed by the Cape Cod prototype. All of the Network programs except one received Cape Cod's highest priority ranking; visitor impact monitoring was ranked given a mid-level ranking (see Table 1 in Appendix 27).

Table 15. The number of vital signs by priority rank chosen for each habitat and management issue.

			Ecosystems		
Rank	**Estuary**	**Salt Marsh**	**Beach**	**Uplands**	**Freshwater**
High	25	20	18	13	14
Medium	7	5	6	6	4
Low	10	8	8	1	4
Total	42	33	32	20	22

			Management Issues		
Rank	**Shoreline Change**	**Water Quality**	**Species & Habitats**	**Resource Extraction**	**Visitor Use**
High	23	24	25	10	17
Medium	5	6	9	3	5
Low	12	6	9	2	1
Total	40	36	43	15	23

Chapter 4 Sampling Design

Chapter 5 Sampling Protocols

Chapter 6 Data Management

Chapter 7 Data Analysis and Reporting

Chapter 8 Implementation of the Monitoring Program

Chapter 9 Schedule

Chapter 10 Budget

Chapter 11 Literature Cited

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